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Summaries of Arkansas Cotton Research 2003

Derrick M. Oosterhuis
University of Arkansas, Fayetteville

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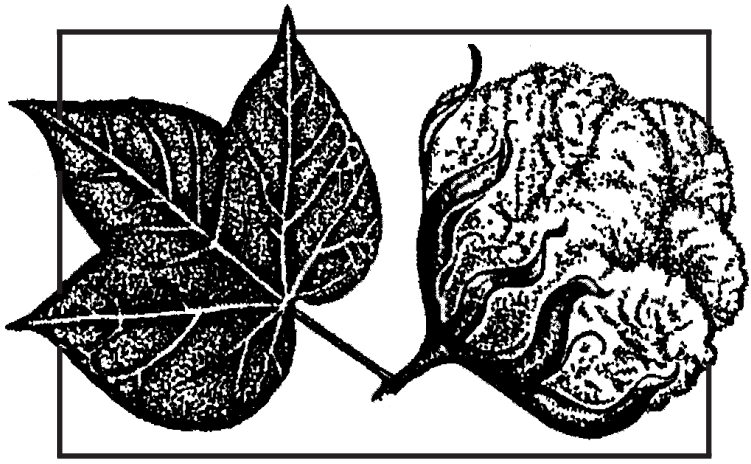

Edited by Derrick M. Oosterhuis

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CONTRIBUTORS

Agudelo, P., Graduate Assistant, Plant Pathology Department, Fayetteville
Arevalo, L.M., Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Avila, C.A., Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Baker, W.H., Northeast Research and Extension Center, Keiser
Barham, J.D., Research Specialist, Southwest Research and Extension Center, Hope
Barrentine, J.L., Professor and Head, Crop, Soil, and Environmental Sciences Department, Fayetteville
Bateman, R.J., Extension Associate III, Southwest Research and Extension Center, Hope
Bibi, A.C., Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Bourland, F.M., Director Northeast Research and Extension Center, Keiser
Branson, J., Rice Research Specialist, Rice Branch Station, Stuttgart
Brown, R.S., Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Bryant, K.J., Area Extension Specialist-Farm Management, Southeast Research and Extension Center, Monticello
Burgos, N.R., Assistant Professor, Crop, Soil, and Environmental Sciences Department, Fayetteville
Burke, T., Research Specialist, Crop, Soil, and Environmental Sciences Department, Fayetteville
Capps, C.D. , Pest Management Technical Support Specialist, Southeast Research and Extension Center, Monticello
Coker, D.L., Research Specialist, Crop, Soil, and Environmental Sciences Department, Fayetteville
Edmund, R., DuPont Field Representative, DuPont Agricultural Products, Little Rock
Dighe, N.D., Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Evans, E.R., Farm Foreman, Soil Testing and Research Lab, Marianna
Feng, C., Professional Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Glover, R.E., Research Specialist, Northeast Research and Extension Center, Keiser
Gonias, E.D., Graduate Assistant, Crop, Soil, and Environmental Sciences, Fayetteville
Greene, J.K., Extension Entomologists, Southeast Research and Extension Center, Monticello
Groves, F.E., Research Specialist, Southeast Branch Experiment Station, Rohwer

Harmon, B., Cooperative Extension Agent-Agriculture, University of Arkansas Cooperative Extension Service, Pine Bluff
Hendrix, B., Technical Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Hogan, R., Extension Economist, Northeast Research and Extension Center, Keiser
Johnson, D.R., Pest Management Section Leader and IPM Coordinator, Cooperative Extension Service, Little Rock
Kelly, M., Weed Science Program Tech, Southeast Research and Extension Center, Hamburg
Kennedy C.E., Resident Director, Cotton Branch Station, Marianna
Kirkparick, T.L., Plant Pathologist, Southwest Research and Extension Center, Hope
Kulari, S., Graduate Assistant, Biological Engineering Department, Fayetteville
Lentz, G.L., Associate Professor, Entomology and Plant Pathology Department, Jackson, Tennessee
Lewis, H., Farmer and Scientist, Hal Lewis Enterprises, Doddridge
Lorenz, G.M., III, Extension Entomologist, Cooperative Extension Service, Blytheville
McClelland, M.R., Senior Research Associate, Crop, Soil, and Environmental Sciences Department, Fayetteville
McConnell, J.S., Associate Professor, Crop, Soil, and Environmental Sciences Department, Fayetteville
McKenzie, A., Associate Professor, Department of Agricultural Economics and Agribusiness, Fayetteville
Matthews S., County Extension Agent, Arkansas Cooperative Extension Service, Blytheville
Monfort, W. S., Graduate Assistant,
Mozaffari, M., Research Assistant Professor, Soil Testing and Research Lab, Marianna
Murphy, J.B., Professor, Horticulture Department, Fayetteville
Myers, B., Research Specialist, Southeast Branch Station, Rohwer
Nichols, B., Project Director, Cotton Incorporated, Cary, North Carolina
Oosterhuis, D.M., Distinguished Professor, Crop, Soil, and Environmental Sciences Department, Fayetteville
Parsch, L., Associate Professor, Department of Agricultural Economics and Agribusiness, Fayetteville
Plunkett, D.E., Cotton Verification Coordinator, Cooperative Extension Service, Little Rock
Reeves, J., Associate Director, Cotton Incorporated, Cary, North Carolina
Robbins, R.T., Professor, Plant Pathology Department, Fayetteville
Robertson, W.C., Extension Agronomist-Cotton, University of Arkansas Cooperative Extension Service, Little Rock
Rodriguez, G., Research Specialist, Department of Agricultural Economics and Agribusiness, Fayetteville

Rothrock, C.S., Professor, Department of Plant Pathology, Fayetteville
Slaton, N.A., Assistant Professor, Crop, Soil, and Environmental Sciences Department, Fayetteville
Smith K.L., Extension Weed Scientist, Southeast Research and Extension Center, Monticello
Smith, P.R., Extension Program Technician Pest Management, University of Arkansas Cooperative Extension Service, Little Rock
Sparks, O.C., Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Stauber, L.G., Seed Agronomist, Diana Growseed, Marion
Stewart, J. M., Professor, Crop, Soil, and Environmental Sciences Department, Fayetteville
Stewart, J., Agricultural Engineer, Engineering Department, Arkansas State University, Jonesboro
Studebaker, G., Entomologist, Northeast Research and Extension Center, Keiser
Tacker, P.L., Agricultural Engineer, University of Arkansas Cooperative Extension Service, Little Rock
Talbert, R.E., Professor, Crop, Soil, and Environmental Sciences Department, Fayetteville
Tingle, C., Agronomist, Northeast Research and Extension Center, Keiser
Van Tol, N. B., Research Associate, West Tennessee Experiment Station, Jackson, Tennessee
Vories, E.D., Professor, Department of Biological and Agricultural Engineering, Northeast Research and Extension Center, Keiser
Williams, K.R., County Extension Agent, Cooperative Extension Service, Hamburg
Worlow, J.M., Research Assistant, Arkansas State University, Jonesboro

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PREFACE

Despite an inauspicious start to the season, the 2003 cotton crop in Arkansas was a bumper crop with record yields of 916 lb lint/acre from 945,000 acres harvested. The high yield for the state matched the five-year *irrigated average* for the state. Three-bale cotton yields were common in portions of southeast Arkansas.

The season started off with an early planting window in mid-April, but thereafter conditions deteriorated with cool wet weather, and poor emergence, and slow seedling development. Northeast Arkansas suffered the most from flooding conditions–at one point the rainfall was measured in feet! As one farmer in Crittenden County stated " it can't get any wetter, just deeper." By the last week in May most of south Arkansas was planted. Poinsett County was particularly hard hit with approximately 60% of the cotton being planted the last week in May. Approximately half of the acreage in northeast Arkansas was in need of replanting. Seedling disease, hard rains, and blowing sand resulted in much of the above mentioned replants. Weed pressures of pigweed seem to continue to build upon of the previous year. Resistant horse weed was verified in Mississippi and Poinsett counties. The resistance was reported as far south as Lee County. Once the crop was planted, rainfall patterns were very timely for the most part. Both daytime and nighttime temperatures were very favorable, with few nights exceeding 74°F and day temperatures seldom reaching 100°F.

Early-season pests were light and insect pressures were not excessive. Mid-and late-season insect pests were more plentiful. Plant bugs were extremely difficult to manage. Fall armyworm numbers were high by seasons' end. Bollworms appeared to be more common in Bollgard cotton. Bollgard II cotton performed well in university testing with regard to improved insect-pest control. Boll weevil eradication efforts were conducted statewide for the first time as fall diapause began in Mississippi and eastern Craighead Counties. The controversy of this effort will likely continue for some time.

Generally speaking, all the harvest-aid products worked well. Cottonseed was of good quality for planting purposes. The micronaire was a lot higher than expected, considering the lateness of the crop, with almost twenty-five percent of the bales classed with a micronaire value of 5 or greater. Fiber qualities of newer varieties were improved to some degree with regard to micronaire, although fiber length (staple) has not changed greatly over the last few years. As textile mills continue to move overseas in response to cheap labor it is important for us to furnish this changing market with the quality they expect. Pounds of lint per acre are certainly important, but the quality of the lint we produce can and does impact the bottom line.

Derrick Oosterhuis and William Robertson.

Weekly Maximum and Minimum Temperature and Rainfall Compared with 32-average
1 April-30 September
West Memphis, Arkansas, 2003

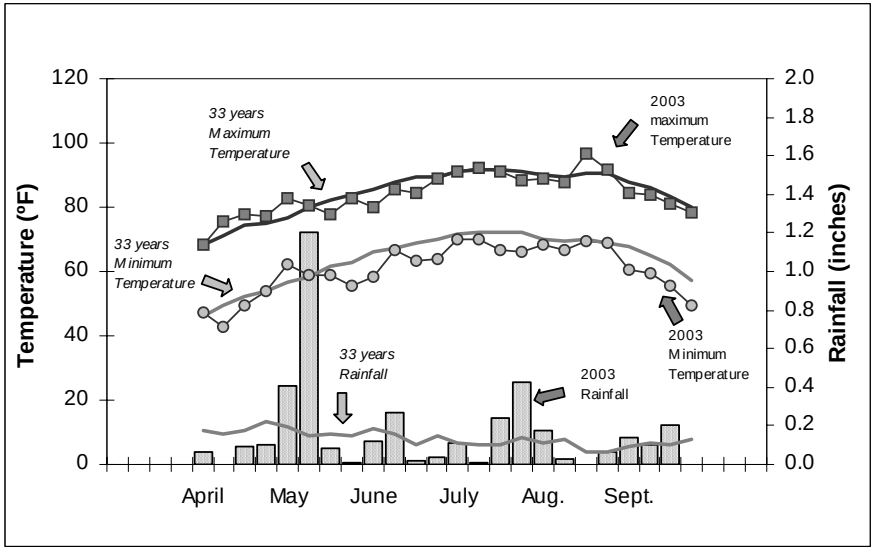

Fig. 1. Weekly maximum and minimum temperatures and rainfall for 2002 compared with the long-term 31-year averages at West Memphis.

ARKANSAS COTTON RESEARCH GROUP 2003/2004

The University of Arkansas Cotton Group is composed of a steering committee and three sub-committees representing production, genetics, and pest management. The group contains appropriate representatives in all the major disciplines as well as representatives from the Cooperative Extension Service, the Farm Bureau, the Agricultural Council of Arkansas, and the State Cotton Support Committee.

The objective of the Arkansas Cotton Group is to coordinate efforts to improve cotton production and keep Arkansas producers abreast of all new developments in research.

Steering Committee: Fred M. Bourland, Gus Lorenz, Gene Martin, Robert McGinnis, Derrick M. Oosterhuis (Chm.), Donald Plunkett, Bill Robertson, Craig Rothrock, James McD. Stewart, Cecil Williams, David Wildy, and Jerry Williams

Pest Management: Jeremy K. Greene, Donald R. Johnson, Terry L. Kirkpatrick, Tim Kring, Gus Lorenz, Bill Robertson, Craig Rothrock (Chm.), Kenneth L. Smith, Don Steinkraus, Glenn Studebaker, Tina Teague, Chris Tingle, Phil Tugwell, and Seth Young

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Genetics: Fred M. Bourland, Hal Lewis, Bill Robertson, and James McD. Stewart (Chm.)

ACKNOWLEDGMENTS

The organizing committee would like to express appreciation to Paula Ehrle for help in typing this special report and formatting it for publication.

COTTON INCORPORATED AND THE ARKANSAS STATE SUPPORT COMMITTEE

The *Summaries of Arkansas Cotton Research 2003* has been published with funds supplied by the Arkansas State Support Committee through Cotton Incorporated.

The principal purpose of Cotton Incorporated is to increase the profitability of cotton production by building demand for U.S. cotton. The Arkansas State Support Committee of Cotton Incorporated is a board whose voting members are cotton growers from Arkansas. Advisory members include representatives of Arkansas' certified producer organizations, the University of Arkansas, the Cotton Board, and Cotton Incorporated. Five percent of Cotton Incorporated's total budget is allocated for research and promotional activities, as determined by the State Support Committees of the cotton-producing states. The sum allotted to Arkansas' State Support Committee is proportional to Arkansas' contribution to the total U.S. cotton fiber production and value in the five years previous to the budget.

The Cotton Research and Promotion Act is a federal marketing law. The objective of the act is to develop a program for building demand and markets for U.S. cotton. The Cotton Board, based in Memphis, Tennessee, was created to administer the act and is empowered to contract within an organization with the capacity to develop such a program. Cotton Incorporated, with its main offices in Cary, North Carolina, the center of the U.S. textile industry, is the contracting agency. Cotton Incorporated also maintains offices in Osaka, Japan; Mexico City; Shanghai, China; and Singapore, Malaysia, to foster international sales. Both the Cotton Board and Cotton Incorporated are non-profit entities with governing boards comprised of cotton growers and cotton importers. The budgets of both organizations are annually reviewed and approved by the U.S. Secretary of Agriculture.

Cotton production research is supported, in part, in Arkansas both by Cotton Incorporated (directly from its national budget) and by the Arkansas State Support

Committee (from its formula funds). Several of the projects described in this research series publication, including publication costs, are supported wholly or in part by these means.

Arkansas Cotton State Support Committee / Cotton Incorporated Funding 2003.

Projects	Researcher	Short title	$ Funding
Cottonseed	Staff	Cottonseed improvement	5,000
01-60AR	Robertson	Herbicide drift	12,000
02-191AR	Greene	Stink bug threshold	15,500
02-192AR	Guy	Large-plot variety trials	10,000
02-193AR	Kring	New aphid thresholds	11,787
02-291AR	Oosterhuis	Research summaries	6,500
03-349AR	Teague	Stress Indices	14,400
04-439AR	Kirkpatrick	Reniform nematodes	18,488
04-440AR	Oosterhuis	Mid-season high temp.	18,000
04-441AR	Oosterhuis	Nitrogen status	1,300
04-442AR	Oosterhuis	PGR x BT x Location	2,950
04-443AR	Oosterhuis	Early-season low temp.	15,300
04-444AR	Robertson	Late-planted cotton	16,790
04-445AR	Robertson	Technology transfer	25,130
04-446AR	Robertson	Defoliation timing	19,140
04-447AR	Talbert	Marestail management	18,661
04-470AR	Bourland	Yield components	26,130
04-476AR	Baker	Remote sensing	23,814
04-477AR	Robertson	Sub-surface drip	15,570
04-491AR	Greene	Stink bugs in BG 11	13,000
04-492AR	Teague	Irrigation x insects	19,283
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Total:			$309,283

SUMMARIES OF ARKANSAS COTTON RESEARCH IN 2003


UofA
UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE

UNIVERSITY OF ARKANSAS COTTON BREEDING PROGRAM - 2003 PROGRESS REPORT

F.M. Bourland[1]

RESEARCH PROBLEM

The University of Arkansas Cotton Breeding Program attempts to develop cotton genotypes that are improved with respect to yield, host-plant resistance, fiber quality, and adaptation to Arkansas environments. Such genotypes would be expected to provide higher, more consistent yields with fewer inputs. To maintain a strong breeding program, continued research is needed to develop techniques that will identify genotypes with favorable genes, combine those genes into adapted lines, then select and test derived lines.

BACKGROUND INFORMATION

Cotton breeding programs have existed at the University of Arkansas since the 1920's (Bourland and Waddle, 1988). Throughout this time, the primary emphases of the programs have been to identify and develop lines that are highly adapted to Arkansas environments and possess good host -plant resistance traits. Bourland (2003) provided the most recent update of the current program.

RESEARCH DESCRIPTION

Each year, breeding lines and strains are tested at multiple locations in the University of Arkansas Cotton Breeding Program. The breeding lines are developed and evaluated in non-replicated tests, which include initial crossing of parents, individual plant selections from segregating populations, and evaluation of the progeny grown from seed of the individual plants. Once the segregating populations are established, each sequential test provides screening of genotypes to identify ones with specific performance capabilities. Selected progeny are carried forward and evaluated in replicated strain tests at multiple Arkansas locations to determine their yield, fiber quality, host-plant resistance, and adaptation properties. Superior strains are subsequently evaluated over multiple years and in regional tests. Improved strains are used as parents in the breeding program and/or released as germplasm or cultivars. Bourland (2004) described the selection criteria presently being used.

[1] Director, Northeast Research and Extension Center, Keiser.

RESULTS AND DISCUSSION

Early-season conditions in 2003 were characterized by cooler and wetter than normal. Consequently, many tests required either re-planting or delayed planting. Variation in stands and early-season growth restricted confidence in the results of many tests. Except for relatively cool conditions during defoliation (September), growing conditions throughout the rest of the season were excellent.

Breeding Lines

The primary focus of breeding line crosses in the last three years has been to enhance yield components or improve resistance to root knot nematode. In 2003, 28 new crosses, 36°F_2 populations, 14°F_3 populations, 192°F_4 1st cycle progeny from 28 progeny, 790 F_5 2nd cycle progeny selected from 88 1st cycle progeny, and 74 advanced progeny from 54 2nd cycle progeny were evaluated. Bolls were harvested from superior plants in the F_2 and F_3 populations and bulked by population. A total of 780 plants were selected from superior F_4 progeny, and 257 superior F_5 progeny were advanced, and 54°F_6 advanced progeny were promoted to strain status.

In addition, 237 individual plants were selected from 30 populations, which have at least one root knot-resistant parent. Progeny from these plants will be evaluated for root knot resistance in the greenhouse and will be planted in field plots in 2004. Progeny with good resistance and field performance will be advanced.

Strain Evaluation

In 2003, 108 strains were evaluated in replicated strain tests at multiple locations. Within each test, strains were compared to standard cultivars (PSC 355 and SG 105). Based on their performance, 36 of the strains were selected and entered into 2004 strain tests. The superior strains exhibited a wide range of lint percentages, leaf pubescence, maturity, and fiber quality. Advanced strains were tested for host-plant resistance (thrips, tarnished plant bug, bacterial blight, fusarium wilt) and were evaluated in regional strain tests and the Arkansas Cotton Variety Test.

Marginal bract trichome studies

Two thesis projects are evaluating marginal bract trichomes in cotton. The first project is determining sampling procedures, variation among cultivars and relationship to other plant trichomes. Marginal trichomes have been found to decline as bract ages (from top to bottom of plant and with sampling date), but the

rate of decline is consistent over cultivars with contrasting numbers of trichomes. Within years, significant cultivar-by- location effects were only found when a highly stressed location was included. These results indicate that marginal bract trichomes of cultivars can be characterized by sampling at a constant plant position on one date at one non-stress location. Smooth-leaf cultivars have fewer marginal bract trichomes than hairy-leaf cultivars, but number of marginal bract trichomes vary significantly within both smooth-leaf and hairy-leaf cultivars. A second thesis project is investigating the inheritance of marginal bract trichomes.

Yield component studies

Two most basic yield components (number of seed per acre and weight of lint per seed) were evaluated in a study of 10 contrasting cultivars in four plant densities at two locations in 2002 and 2003.

Yield, yield components, and fiber data have been collected for whole plots and for individual tagged bolls. The tagged bolls were produced from three flowering dates and represent different areas of the plant. In addition, a study of the inheritance of these yield components is underway. Results from these studies should help to better understand relationships of yield and fiber traits and to develop breeding strategies to improve yield, yield stability, and fiber quality.

PRACTICAL APPLICATION

Genotypes with improved host-plant resistance, improved yield and yield stability, and good fiber quality are being developed. Improved host-plant resistance should decrease production costs and risks. Selection based on yield components may help to identify and develop lines having improved and more stable yield. Lines with fewer bract trichomes may reduce the amount of lint cleaning required to attain acceptable trash grades. These genotypes should be valuable as breeding material to commercial breeders or released as cultivars. In either case, Arkansas cotton producers should benefit from having cultivars that are specifically adapted to their growing conditions.

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DEVELOPMENT OF MOLECULAR MARKERS TO DISTINGUISH CYTOPLASM SUBSTITUTION LINES OF COTTON

T. Burke and J. McD. Stewart[1]

RESEARCH PROBLEM

Traditionally breeders and geneticists alike have used morphological characteristics or phenotype to distinguish various genotypes/cultivars. However, with the advent of cytoplasmic capture, phenotyping can become difficult, if not impossible. Through this process, lines with new cytoplasms (alloplasmic lines) differ in their cytoplasmic material but have the same nuclear DNA. Since nuclear DNA is the primary basis of heredity, notable morphological differences may not be seen, thus making phenotype selection difficult or impossible. In recent years, molecular measures have provided a sensitive and reliable means to identify diversity among genotypes. Both geneticists and plant breeders have come to rely on marker assisted selection (MAS) as a proven and powerful tool for screening and selection. The objective of this project is to develop molecular markers for chloroplastic or mitochondrial DNA, as a means to identify different cytoplasm substitution lines.

BACKGROUND INFORMATION

Genetic diversity is believed to provide a buffer against adverse effects such as sudden increases in the virulence of pathogens or pests, or rapid changes in the environment. In the United States, the danger of genetic vulnerability of major modern crops was illustrated graphically by the epidemic of the Southern corn leaf blight, which caused a 15 % reduction in corn output in 1970 (Wright, 1996). The majority of corn hybrids at that time shared a common Texas male-sterile cytoplasm that was used because it greatly facilitated hybrid seed production. This cytoplasm, and all hybrids using the cytoplasm, proved to be highly susceptible to a race of Southern corn leaf blight (Anonymous, 1997). This epidemic came as a shock to crop breeders and geneticists and exposed the vulnerability of reliance on a narrow genetic base for important agricultural crops. The result was a widespread effort to invest in *ex situ* preservation and research on germplasm

[1]Research specialist and professor, respectively, Crop, Soil, and Environmental Sciences Department, Fayetteville.

resources. Our greatest opportunity to reduce or minimize genetic vulnerability in cotton lies in greater and more efficient use of our feral and/or exotic germplasm (Anonymous, 1997).

In an effort to increase genetic diversity and reduce disease or insect susceptibility, the cytoplasms of eleven *Gossypium* species have been introduced into the *G. barbadense* (AD2) nuclear genetic background (Stewart, 1990). *G. barbadense* was chosen as the nuclear donor because it contains the semigamy trait that gives rise to haploid male/female chimeric plants. Using this trait, a completely new nucleus, such as an elite line of upland cotton, can be transferred into the cytoplasm in one generation rather than through years of successive backcrossing. Genetic markers are necessary to readily distinguish among these alloplasmic lines and any new lines that may be developed.

RESEARCH DESCRIPTION

The *Gossypium* species cytoplasms examined in this study are listed in (Table 1). Seeds were sown in pots under optimal conditions in a greenhouse at Fayetteville, Arkansas. DNA was extracted from leaf tissue using the CTAB miniprep method of Zhang and Stewart (2000). DNA was quantified using a spectrophotometer to measure absorbance at 260 nm, and then it was diluted to 20ng/:l. Polymerase chain reactions (PCR) were performed using 10 chloroplast simple sequence repeat (cpSSR) primer pairs, as well as 37 specific primer combinations spanning 11 chloroplast genes, introns, and spacers. Genes examined and primers used are listed in (Table 2). Cleaved amplified polymorphism (CAPS) studies were also conducted on larger fragments (fragments >800 bps). Products were digested using BamH1, EcoR1, and MSE1, following manufacturer's protocols. All products were resolved by electrophoresis through a 2% high resolution metaphor agarose gel or on a polyacrylamide gel in TAE and TBE buffers, respectively. All samples were compared to parental (wild type) DNA as a positive control.

RESULTS AND DISCUSSION

Polymorphisms were found in the matK-cpDNA, rpl16-cpDNA, and cpSSR#3 PCR products. PCR with the cpSSR primer yielded four groupings. All the products from the A and B genome, as well as the F_1 alloplasmic line, fell into group number one. Group two included all of the D and C genomes, as well as the E_1 alloplasmic line. E_1 and F_1 species samples fell into separate groups, suggesting a labeling error and loss of the introgressed cytoplasm has occurred. Endonuclease digestion of the matK-cpDNA fragment also yielded two groups. Group-1 encompassed the A, B, and F genomes. Both the $D_{3\text{-}d}$ alloplasmic line and wild species were included in Group-1, while the D_8 and $D_{2\text{-}2}$ alloplasmic lines fell into Group-2 along with the C_1 alloplasmic lines. The E_1 species also fell into Group-1, while the alloplasmic line belonged to Group-2. This further indicates the "E_1"

alloplasmic line does not contain the E_1 cytoplasm. Also, the pattern of the wild C_1 species did not match that of the "C_1" alloplasmic line. Digestion of the rpl16 fragment also yielded two groups, separating the D_8 and B_1 lines from the remaining alloplasms in the study. The identity of these lines was confirmed.

The low level of polymorphisms found among the cytoplasms in relation to the number of primers used and digestions performed can be explained by the highly conserved nature of chloroplast DNA. Chloroplast DNA is inherited maternally and, therefore, remains extremely conserved from one generation to the next. This is also evident in the polymorphisms that were found. Groupings based on DNA polymorphisms almost always included all of the lines from a specific genome, and separated only lines of another genome. With the exception of the $D_{3\text{-}d}$ alloplasmic line, no polymorphisms were found with which to distinguish species cytoplasms within a genomic group. Additional investigation of chloroplast genes, as well as studies aimed at mitochondrial genes, is needed to find specific polymorphisms within each genome. After complete examination, fragments will be cloned, sequenced, and the sequences screened for single nucleotide differences among cytoplasms. Since mitochondrial sequences are less conserved, studies will also be performed on the DNA of this organelle using the same techniques described.

PRACTICAL APPLICATION

The need for genetic markers to distinguish among cytoplasmic substitution lines is apparent by the lack of morphological diversity between the lines. Even with the limited data obtained thus far, the assumed cytoplasmic constitution of three of the alloplasmic lines appears to be incorrect. Observations relative to the influence of cytoplasm on performance of an alloplasmic line are meaningless if the line is incorrectly identified.

ACKNOWLEDGMENTS

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Table 1. List of *Gossypium* cytoplasmns and alloplasmic lines in this study.

Species	Genome	Origin
arboreum	A2	Indian Subcontinent
tomentosum	A3	Hawaiian Islands
mustelimum	AD4	Northeast Brazil
darwinii	AD5	Galapagos Islands
anomalum	B1	Southwest Africa
sturtiamum	C1	Central Australia
harknessii	D2-2	Baja, California
davidsonii	D3-d	Baja, California
trilobum	D8	West Central Mexico
sticjsuu	E1	Arabian Penninsula
longlicalyx	F1	East Central Africa

Table 2. Chloroplast genome area and amplifying primers.

Genes	Primers
rp116-cpDNA[1]	F71, RF-int, R1516, R1661
matK-cpDNA[1]	trnKF, trnKF2, trnKF3, TrnKF4, trnKR
trnT-trnL-cpDNA[1]	trnA2, trnB, trnL2
ndhF-cpDNA[1]	5' Fnew, 536F, 803F, 972F, 3'R, 972R, 1318R
atpB-rbcL spacer[2]	atpB, rbcL
trnL-trnF spacer[2]	E,F
trnT-trnL spacer[2]	A, B, TrnT-I
accD-psaI spacer[2]	accD-769F, accDI, psai-75R
ndha intron[2]	ndhA-F, nahA-R, nahA-I
rpI16 intron[2]	F71,R1661, R1516
rpoCI intron[2]	5'rpoCI exon, rpoCI exon2

[1]Cronn et al. (2002).
[2]Small et al. (1998).

PERFORMANCE OF BOLLGARD II IN ARKANSAS IN 2003

P.R. Smith, G.M. Lorenz, D.R. Johnson, W.H. Robertson, and D. Plunkett[1]

RESEARCH PROBLEM

Bollgard® II was compared to Bollgard® and conventional (i.e., non-*Bt*) cotton in order to observe effectiveness against the Heliothine complex and various lepidopterous pests. In the trial, Bollgard II and Bollgard performed marginally better when compared to conventional cotton with respect to square, bloom, and boll damage. Bollgard II performed significantly better than Bollgard and conventional cotton with respect to soybean looper defoliation. Bollgard and Bollgard II significantly out-yielded conventional cotton. Further evaluations of Bollgard II will be necessary to determine feasibility for Arkansas cotton production.

BACKGROUND INFORMATION

Bollgard® cotton (*Gossypium hirsutum* L.), containing the CryIAc endotoxin of *Bacillus thuringiensis* Berliner, became commercially available to cotton producers in 1996. Since its introduction, Bollgard cultivars have provided cotton producers with effective control of tobacco budworm, *Heliothis virescens* F., in Arkansas. Control of bollworm, *Helicoverpa zea* (Boddie), and various other lepidopterous pest has achieved less reliable control and depended more on foliar insecticide treatments in conjunction with the *Bt* cultivar (Lorenz et al., 2002). Bollgard® II was developed to give additional control as the result of a second toxin, Cry@ Ab. The purpose of this toxin was to increase control of lepidopterous pests and decrease the probability of population resistance of targeted pest. Previously conducted studies have shown Bollgard® II to be effective in controlling bollworm and soybean looper (Allen et al., 2000; Ridge et al., 2000). The purpose of this study was to examine the efficacy of Bollgard® II to Bollgard® and to conventional cotton for control of lepidopterous pests. Additional observations were made to compare agronomic characteristics of these cultivars.

[1]Extension program technician (pest management), University of Arkansas Cooperative Extension Service, Lonoke; IPM coordinator, pest management section leader, University of Arkansas Cooperative Extension Service, Little Rock; extension program technician (pest management), University of Arkansas Cooperative Extension Service, Lonoke; and county extension agent, University of Arkansas Cooperative Extension Service, Jefferson County, Arkansas, respectively.

RESEARCH DESCRIPTION

The study was conducted on the Hooker Farm in Jefferson County, Arkansas. The study was planted on May 23. The test consisted of a randomized complete block design with four replications. The four treatments were the cultivars: Sure-Grow 521R (Non-Bollgard®), Sure-Grow 215 (Bollgard®), and Deltapine 424 (Bollgard® II) with each cultivar treated or untreated with a foliar insecticide. Each plot was 8 rows wide and 50 feet long. Insecticide used in the study was gamma-cyhalothrin (Karate Z). Applications were based on weekly samples taken from mid-June to early August. Application dates using Karate Z were July 9, July 23, and August 4. Sampling data included damaged terminal counts, damaged floral counts, and damaged fruit counts. Plots were machine picked November 3. All data were analyzed using Analysis of Variance and LSD (P=0.05).

RESULTS AND DISCUSSION

Populations of tobacco budworm and cotton bollworm were lower than in recent years. While heliothine pressure was evident in local area fields, the pressure in the trial was somewhat lower.

Results in 2003 showed no significant difference in terminal damage between Bollgard® II, Bollgard®, and conventional cotton (Table 1). Data also showed no significant difference in square damage between Bollgard® II, Bollgard® and conventional cotton. However on the August 19 observation there was a significant statistical difference in the amount of large larvae (greater than 1/4 inch or greater than .0635 cm) observed in conventional cotton when compared to Bollgard II and Bollgard. Likewise on September 2, conventional cotton exhibited a significant difference in the amount of damaged fruit when compared to Bollgard II and Bollgard cotton.

On September 19 visual observations were conducted of a soybean looper-*Pseudoplusia includens* (Walker)- moth flight and subsequent hatching. Data showed significant difference with respect to foliar feeding and defoliation percentage (Table 2). Bollgard II performed significantly better than Bollgard and conventional cotton. Conventional cotton and Bollgard did not significantly differ from one another.

Both Bollgard and Bollgard II out-yielded conventional cotton, however, Bollgard II did not significantly out-yield Bollgard. The automatic late-season application treatment of Bollgard II yielded statistically similar to conventional cotton, and therefore less than the threshold spraying of Bollgard II. Additional data are needed to determine the feasibility of Bollgard II in Arkansas.

PRACTICAL APPLICATION

Like Bollgard, Bollgard® II has the capability to impact growers by reducing the amount of applications needed to control Heliothine pest. This also has the potential to increase profit margins for growers.

ACKNOWLEDGMENTS

We thank Monsanto for providing grant support for this study. We also thank Chuck Hooker for allowing us to use his land.

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Table 1. Seasonal summary of total damaged squares, terminals, bloom and bolls, as well as numbers of larvae and eggs, and lint yield.

Treatment (lb ai/a)	TPB 2DAT1	TPB 7DAT1	TPB 2DAT2	TPB 4DAT2	TPB 7DAT2	TPB 2DAT3	TPB 4DAT3	TPB 8DAT3	Lint Yield
UTC	27.8a-c	20.8abc	11.8abc	10.5a	8.5ab	5.5a	2.3abc	2.8ab	930.5g
Diamond 0.058	33.0abc	4.3d	5.0def	20.d	1.0ef	1.8cd	1.3bc	1.0bcd	977.5efg
Diamond 0.078	37.5a	14.0cd	6.8c-f	3.3cd	0.8f	1.5cd	1.3bc	0.8cd	1072.7c-g
Mustang Max 0.018	30.5 a-d	15.8bc	14.3a	9.5ab	9.3a	2.8bc	4.0a	1.5bcd	986.9d-g
Mustang Max 0.025	35.3ab	25.5ab	13.0ab	8.5ab	6.5abc	4.8ab	2.8ab	3.5a	940.3fg
Centric 0.0375	15.5cde	13.5cd	4.0def	3.0d	4.5cd	1.3cd	0.3c	0.0d	1271.3a
Bidrin 0.33	22.3a-e	20.0abc	1.8f	1.8d	0.5f	0.5d	1.0bc	0.3cd	1083.2b-f
Orthene 97 0.33	32.3abc	17.0abc	3.5ef	2.0d	1.8def	0.0d	0.3c	0.5cd	1060.7c-g
Leverage 0.07	12.8a-e	17.5abc	8.0b-e	3.5cd	4.8cd	1.5cd	1.8bc	2.0abc	1200.6abc
Double Threat	14.3de	26.3a	4.0def	9.0ab	4.3cde	1.8cd	1.3bc	1.3bcd	1023.8d-g
Trimax 0.047	18.8b-e	12.0cd	6.8c-f	4.0cd	5.5bc	1.5cd	0.8bc	2.0abc	1200.6abc
Curacron	26.3a-e	18.3abc	9.3a-d	6.5bc	3.5c-f	2.8bc	0.3c	1.8a-d	1110.3b-e
Vydate 0.33	19.3b-e	20.0abc	1.8f	2.5d	2.0def	0.8cd	0.3c	0.5cd	1128.4a-d

Table 2. Percent defoliation by soybean looper.

Treatment	% Soybean Looper Defoliation
Non-Bt	22.5a[1]
Bollgard	26.3a
Bollgard II (sprayed for Lep. on threshold)	2.5b
Bollgard II (automatic late-season highest labeled rate phrethroid)	0b

[1]Means followed by the same letters are not significantly different (P=0.05).

VARIETAL RESPONSES OF COTTON TO NITROGEN FERTILIZATION[1]

J.S. McConnell, B.A. Myers, and M. Mozaffari[2]

RESEARCH PROBLEM

Optimizing yield and earliness of cotton (*Gossypium hirsutum* L.) varieties with nitrogen fertilization is an ongoing concern of cotton producers in Arkansas (Maples and Frizzell, 1985; McConnell, et al., 1993). Genetically engineered cotton varieties are currently being used in increasingly larger portions of the cotton-producing acreage of Arkansas and the Cotton Belt. Producers have been quick to utilize 'Bollgard' and Roundup® ready varieties, as well as 'stacked gene' varieties that combine these two technologies into one cotton variety. Advantages of these new varieties include higher yield potential, enhanced pest resistance, resistance to herbicides, superior lint quality, faster maturity, and other new characteristics. With the increased use of new cotton varieties in Delta production systems, N requirements of the new varieties are often questioned by producers. The objective of this study was to determine various responses of new, genetically engineered cotton varieties to N-fertilization; particularly yield, earliness, and fiber quality.

BACKGROUND INFORMATION

New cotton cultivars have increased the genetic diversity of cotton grown in the Delta. The genetic variability of currently available varieties indicates that crop management practices, such as fertilization, required to achieve optimum yields and earliness might differ from older varieties. Optimizing N fertilization for individual cotton cultivars is one possible way of tailoring production practices to achieve optimal economic returns.

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[1] This manuscript was reprinted from: Nathan Slaton (ed.), Wayne E. Sabbe Arkansas Soil Fertility Studies 2003, University of Arkansas Agricultural Experiment Station Research Series 515:32-33.

[2] Associate professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; research specialist, Southeast Branch Station, Rohwer; and research assistant professor, Soil Testing and Research Laboratory, Marianna, respectively.

PROCEDURES

Studies of the responses of cotton varieties to N-fertilization were begun at the Southeast Branch Experiment Station in 1989 (McConnell et al, 1993). Tested varieties have changed as new varieties have been introduced into the Delta region. Varieties currently under evaluation are: Stoneville 4892 BR (ST 4892BR), FiberMax 960 BR (FM 960BR), Pay Master (PM 1281BR), and Deltapine 555 BR (DP 555BR). All varieties tested are genetically engineered to tolerate early-season applications of Roundup® herbicide, and to resist damage from heliothis species insect pests. This is the first year of results from tests including these new varieties.

Fertilizer treatments were 0, 50, 100, and 150 lbs N/acre. The source of the N was urea. The N-fertilizer treatments were split-applied with half the total N-rate applied after emergence and half when the crop reached the first square stage. The urea-N was incorporated with shallow plowing after each application. Plot integrity has been maintained with respect to N-rates. The same N-treatments have been applied to the same plots since the inception of testing. The test was furrow-irrigated using tensiometers to trigger irrigation. The varieties were planted on May 12, 2003. The soil (Hebert silt loam) at the test site was sampled and analyzed for nutrient content in 1999 (Table 1).

The measurements taken on the cotton varieties included seedcotton yield, plant height, plant population, and node development information. All data were analyzed using the Statistical Analysis System (SAS). The experimental design was a randomized complete block. F-tests and least significant differences (LSD) were calculated at the á=0.05 level of probability. Only yield responses of cotton to N-fertilization are presented in this report.

The 2003 growing season was marred by abnormally wet and cool growing conditions in May and most of June. These inclement conditions were responsible for substantially delayed maturity in the 2003 crop. Yields were lower than expected and lower than other years of similar testing (McConnell et al., 2003).

RESULTS AND DISCUSSION

No significant differences in the yield of cotton occurred as a function of the interaction between cotton variety and N-fertilizer rate (Table 2). Seedcotton yields among varieties, averaged across N rates, were not statistically different. The mean yield of PM 1281BR, the numerically greatest-yielding variety, was only 233 lb/A greater than the yield of ST 4892BR, the numerically lowest-yielding variety.

Although yields were lower in 2003 than in preceding years, significant differences in cotton yield were observed among N rates, averaged across varieties. The 50 lb N/acre rate produced a 73% increase in yield from the untreated control. The 100 lb N/acre rate produced a 24% increase in yield above 50 lb N/acre. The 150 lb N/acre rate produced the maximum yields and was 12% greater than the mean cotton yield from 100 lb N/acre. All differences among the N-treatment

means were statistically significant.

PRACTICAL APPLICATION

Nitrogen fertilization rate was the only factor that affected seedcotton yield in 2003. These first-year results suggest that genetically engineered cotton varieties have similar N fertilizer requirements and do not likely require different N-fertilizer management strategies than conventional cotton varieties.

ACKNOWLEDGMENTS

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Table 1. Residual nitrate-nitrogen (No_3-N), phosphorus (p), potassium (k), soil ph, and electrical conductivity (EC) to a depth of two feet in six-inch increments from the variety by N-fertilization rate in test site in 1999.

Depth	No_3-N	P†	K†	pH‡	EC‡
(inches)		----------(lbs/acre)----------			(S/m)
0-6	1.8	70	260	6.3	26
6-12	1.7	30	125	6.4	20
12-18	1.7	29	149	6.1	21
18-24	2.4	22	243	6.0	44
LSD(0.05)	0.4	6	18	0.1	3

† Mehlich-3 extractable (1:7 extraction ratio).
‡ Soil pH and EC measured in a 1:2 soil-water mixture.

Table 2. Seedcotton yields of four genetically engineered cotton cultivars as affected by N fertilizer rate at the Southeast Branch Experiment Station near Rohwer, Ark., during 2003.

	Cotton cultivar and yield				
N Rate	ST 4892BR	FM 960BR	PM 1281BR	DP 555BR	Mean
	----------(lb seedcotton/acre)----------				
150	3590	4219	3903	3805	3869
100	3514	3570	3476	3246	3467
50	2616	2788	3095	2648	2787
0	1820	1721	1428	1479	1612
		LSD (0.05) to compare N-rate means=67lb/acre			
Mean ‡	2807	29890	3040	2869	--

† Lint yield may be estimated by dividing seed cotton yield by 3.
‡ Mean yields of cultivars, averaged across N rates, were not different.

ECONOMIC EFFECT OF LATE IRRIGATION ON ARKANSAS COTTON

R. Hogan, Jr., E.D. Vories, J.K. Greene, J. Stewart, W.H. Robertson, and P.L. Tacker[1]

RESEARCH PROBLEM

Studies have been conducted throughout the mid-South since 2000 to determine the optimal time for the last irrigation on cotton based upon nodes above white flower. This report presents a methodology to combine the results from different studies at different locations in different years and develop a recommendation. Data from 12 Arkansas studies spanning four years were included in this analysis.

BACKGROUND INFORMATION

Cotton growers across the Cotton Belt are adopting COTMAN, a COTton MANagement system developed at the University of Arkansas, to monitor crop development and aid in making end-of-season decisions (Danforth and O'Leary, 1998). The later-season portion of the system is based on monitoring the number of nodes above the uppermost first-position white flower (NAWF) on a plant. Bourland et al. (1992) found that a first-position white flower five nodes below the plant terminal represented the last effective flower population. Based on their findings, NAWF=5 is generally accepted as physiological cutout (Oosterhuis et al., 1999). The COTMAN system uses a target development curve (TDC) as a reference to compare with actual crop development. The TDC has flowering beginning at 60 days after planting (DAP) and NAWF=5 at 80 DAP. Comparisons of actual crop development to the TDC provide an indication of the maturity of the crop. Early-season stress often results in first flower at a relatively low NAWF value and physiological cutout occurring in less than 80 DAP. Research projects underway in Arkansas and other cotton-producing states are focused on using the information from COTMAN to aid in additional management decisions, including when to stop irrigating the crop. Developing a recommendation that reliably relates the timing of the final irrigation to physiological cutout will require combining the data from many different studies conducted under different environments.

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[1] Extension Economist, professor. Northeast Research and Extension Center, Keiser; extension entomologist, Southeast Research and Extension Center, Extension Center, Monticello; agricultural engineer, Engineering Department, ASU, Jonesboro; extension agronomist-cotton, and agricultural engineer, Cooperative Extension Service, Little Rock; respectively.

RESEARCH DESCRIPTION

Since 2000, Cotton Incorporated has sponsored studies in four mid-South states (Missouri, Arkansas, Mississippi, and Louisiana) to determine the optimal time to terminate furrow irrigation of cotton. Vories et al. (2001) reported on studies at three northeast Arkansas locations in 2000; Vories et al. (2002) reported on another eight mid-South studies in 2001; Vories et al. (2003) reported on eleven mid-South studies in 2002; and Vories et al. (2004) reported on seven mid-South studies in 2003.

Data from 12 Arkansas studies spanning four years (a total of 201 data points) were included in this analysis. Final irrigations occurring before NAWF=5 were removed from the data set. Data from some of the studies were not available at the time of this report. Additional (marginal) yield due to an additional irrigation treatment was computed for the treatments. Additional (marginal) revenue was then calculated based on a series of possible market cotton lint prices (e.g., $0.35, 0.45, 0.55, 0.65, and 0.75 per pound of lint). Additional revenue will be called marginal revenue and additional cost will be called marginal cost hereafter.

RESULTS

The model was specified as a cubic polynomial with marginal yield as a function of the number of heat units (DD60's) past NAWF=5 as shown in

$$MY = 1.7*DD^3 - 24.3*DD^2 + 86.7*DD - 20.8, \qquad (1)$$

where *MY* is the marginal yield, and DD is the number of DD60 heat units after NAWF=5 average for the field. SAS version 8.1 was used to model the equation shown in (1) and the estimates of the parameters. The R^2 for the models was 0.13; though this number may seem low in some scientific disciplines, it is satisfactory when dealing with economic data.

Marginal revenue (MR) is the product of marginal yield and lint price. The level of optimal net revenue will occur at that point where marginal revenue derived from an extra irrigation treatment is equal to the marginal cost of that treatment. Marginal cost of furrow irrigation was assumed to be $4.14 per acre (Bryant et al., 2001) based on conditions typical for Arkansas. Thus the optimal irrigation termination points can be computed by solving the following equation for *DD*.

$$MR = MC = \$4.14, \qquad (2)$$

where *MR* is the marginal yield determined from (1) times the price of lint and *MC* is a constant marginal cost. The optimal solution points for each of the prices are also shown in Table 1.

Each of the marginal revenue equations was graphed along with the marginal cost of an additional irrigation (Fig. 1). The optimal points in DD60 past NAWF=5 were plotted against the corresponding cotton price (Fig. 2). These points were then modeled as the simple linear function

$$DD = 512 + 63.3 * price, \qquad (3)$$

where *price* is the respective cotton lint price in dollars per pound of lint. The change in optimal termination points varied from a low of 529 to a high of 560, a difference of 31 heat units after NAWF=5 from a low cotton price of $0.35 to a high of $0.75 per pound. In Arkansas during the summer, this range can occur within about one day.

PRACTICAL APPLICATION

The data set used in this analysis is fairly limited for this type of study. Further verification and refinement of these conclusions by continued research and farm verification are needed and the analytical procedure can then be repeated as more data become available. Additional investigation of a possible north-south effect must be conducted as more data are collected throughout the mid-South region. Based on these limited data, optimal irrigation termination should occur at NAWF=5 plus 550 DD60 heat units if the estimated market price of cotton is between $0.35 and $0.75 per pound of lint. A wide range in price had little effect on the optimal termination point. This research will continue in 2004.

ACKNOWLEDGMENTS

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Table 1. Optimal irrigation termination points based on lint price.

Cotton price ($/lb)	Heat units past NAWF=5 (DD60)
0.35	529
0.45	552
0.55	541
0.65	553
0.75	560

Fig. 1. Marginal cost versus marginal revenue at various cotton prices.

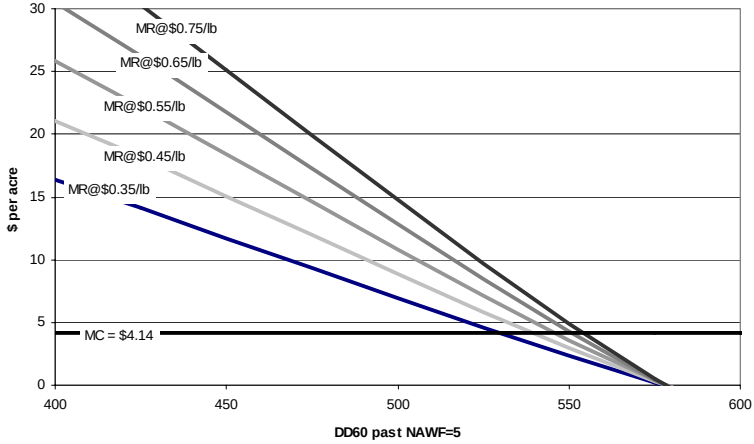
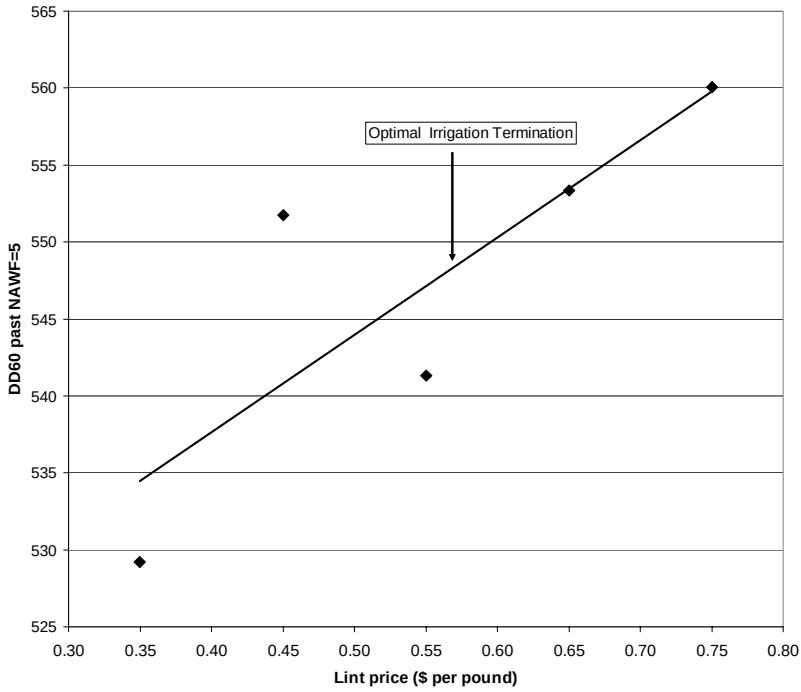


Fig. 2 Cotton price versus optimal irrigation termination point.



LONG-TERM IRRIGATION METHODS AND NITROGEN FERTILIZATION RATES IN COTTON PRODUCTION: THE LAST THREE YEARS OF THE MCCONNELL - MITCHELL PLOTS[1]

J.S. McConnell, B. A. Myers, and M. Mozaffari[2]

RESEARCH PROBLEM

Nitrogen (N) and water management are two very important aspects of successful cotton (*Gossypium hirsutum*, L.) production. If cotton becomes N deficient the plants may become chlorotic and not photosynthesize sufficiently to meet the demands of crop growth. Nitrogen deficiency of cotton typically results in reduced yields, pre-mature cutout, and reduced fiber quality. Few studies of the interactions of N fertilizer and irrigation have been conducted for cotton. This is especially true under the humid production conditions of southeast Arkansas (McConnell et al., 1988). Objectives of these studies were to evaluate the growth, development, and yield of intensively managed cotton as a function of N fertilization and soil N dynamics under different irrigation methods.

BACKGROUND INFORMATION

Both over- and under-fertilization of cotton with N may result in reduced yield. Over-fertilization may also induce delayed maturity in cotton (Maples and Keogh, 1971). Reductions in yield and quality due to N-deficiency may severely reduce the value of the crop and have adverse economic consequences for producers (Bondada et al., 1996; Radin and Mauney, 1984).

Adequate soil moisture is also necessary for cotton to achieve optimal yields. Early- and mid-season water requirements of cotton should be met to avoid yield loss that may occur if the crop undergoes drought stress (Jordan, 1986;). If the soil becomes either too wet or too dry, cotton plants will undergo stress and begin to shed fruit (Guinn et al., 1981). The method of irrigation that maximized yield varied among years, and therefore, appeared to be less important than irrigation usage.

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[2] Associate professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; research specialist, Southeast Branch Station, Rohwer, and research assistant professor, Soil Testing and Research Laboratory, Marianna, respectively.

PROCEDURES

An experiment to examine the interactions of N-fertilization strategy (N-rate and application times) and irrigation methods was initiated at the Southeast Branch Experiment Station on a Hebert silt loam soil in 1982. These experiments, the McConnell-Mitchell Plots, are the oldest continuous plots in Arkansas. The experimental design was a split block with irrigation methods as the main blocks. Four irrigation methods were used from 1982 until 1987. Five irrigation methods were employed from 1988 to 1993. Only three irrigation methods have been used since 1993 (Table 1).

Ten N treatments were tested within each irrigation method. Six different N rates (0, 30, 60, 90, 120 and 150 lb urea-N/acre) were tested with different application rates and timings (Table 2). Nitrogen fertilization was discontinued for the 2000 and subsequent growing seasons (2001 - 2003) to examine the effects of residual soil nitrate-nitrogen (NO_3-N) on cotton development. Soil samples were taken from the plots and analyzed for residual NO_3-N to a depth of five feet in 2000.

The McConnell-Mitchell Plots were planted on 14 May 1999, 18 May 2000, 23 April 2002, and 12 May 2003. The 2001 growing season was marked by an early June hail storm that destroyed the stand of cotton. The cotton was replanted on 15 June 2001, but seedling disease decimated the stand. The crop was not replanted again and the plots were fallowed, as it was deemed too late to get meaningful results. Weeds were controlled with Roundup®. No data was collected due to stand loss. Both the 2002 and 2003 crops were influenced by cool, wet conditions early in the growing season

RESULTS AND DISCUSSION

The interaction between irrigation method and residual soil N from previous N-fertilization significantly affected yields all three years of the study. During the 2000 and 2002 growing seasons, high-frequency irrigation generally increased cotton yields compared to furrow-irrigation or dry-land production. Additionally, furrow-irrigated cotton typically produced greater yields than dry-land cotton during this period.

The cool, wet early season of 2003 substantially delayed cotton development. The supplemental water applied in the irrigated blocks increased plant height (data not shown) and probably total plant weight, but delayed maturity of the crop. The delayed maturity and increased growth resulted in reduced yields for cotton grown in both the high-frequency and the furrow-irrigated blocks (Table 4). Plant response to residual N in 2000 reflected the N-fertilizer application rates from previous years. Maximum yields were produced with the 150- and 120-lb N/acre treatments applied in the high-frequency and furrow-irrigated blocks .

However, yields among N treatments within the dry-land irrigation block were not different. Cool, wet conditions in the 2002 growing season resulted in

severe seedling disease but not stand loss. Near optimal growing conditions through the rest of the season resulted in acceptable yields, however, response to residual NO_3-N was limited in 2002. Cotton yields under high-frequency irrigation did not significantly respond to the residual soil NO_3BN, and cotton under dry-land and furrow-irrigation had only minimal yield response (data not shown). As the residual NO_3-N were consumed by subsequent crops, it had less impact on plant development and yield.

Even worse early-season growing conditions occurred in 2003 than in 2002. Cool, wet weather persisted from early May through June, and delayed growth, development, and squaring of the seedlings. The impaired plants produced the lowest mean yields in the last three years of this study (data not shown). Response to residual soil NO_3-N was not significant in either the High-frequency irrigated or the furrow-irrigated blocks. The lack of yield response in these two blocks indicates that the residual soil NO_3-N may be depleted. Yields significantly increased with residual NO_3-N from previous N fertilization in the dry-land block. The greatest yielding treatments were those testing highest in residual NO_3-N in 2000, and that had previously received 120- to 150-lb N/acre. These results indicate that substantial residual soil NO_3-N still plays a role in plant development of cotton, especially under dry-land production conditions.

PRACTICAL APPLICATION

Irrigated cotton generally produced higher yields than cotton grown under dry-land conditions. Cotton yield response to residual soil N from previous N-fertilization of cotton tended to be greater under irrigated production conditions than under dry-land production conditions. Residual soil N was sufficient the first year to maintain yields when previous years of N-fertilization were high. After three growing seasons and one fallow season, the yield response to residual NO_3-N was negligible for irrigated cotton with only the dry-land block producing seedcotton yields that increased as previous N rate increased.

ACKNOWLEDGMENTS

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Table 1. Duration, tensiometer thresholds and depths, and water application rates for three irrigation methods used in the McConnell-Mitchell Plots since 1993.

Irrigation method	Duration	Tensiometer	Depth	Water applied
		(cbar)	(in.)	(in.)
	Planting to P.B.†	35	6	0.75
'High frequency center-pivot'	P.B. to Aug. 15	35	6	1.00
Furrow-flow	Until Aug 15.	55	12	Not precise
Dry-land	Not irrigated	----------	------	-------

† P.B.=Peak Bloom

Table 2. Nitrogen (N) fertilization treatments and application timings for the McConnell-Mitchell Plots.

N-fertilizer application timings			
Total -N rate	Preplant rate	First square N	First flower N
----------(lbs N/acre)----------			
150	75	75	0
150	50	50	50
150	30	60	60
120	60	60	0
120	40	40	40
90	45	45	0
90	30	30	30
60	30	30	0
30	15	15	0
0	0	0	0

Table 3. Seedcotton yield response to residual N from ten nitrogen (N) fertilization treatments under three irrigation methods during 2003.

N-rate by application time				Irrigation method			
Total N Rate	PP	FS	FF †	High frequency	Furrow-irrigated	Dry-land	N-rate Mean
----------(lbs N/acre)----------				-------- lbs seedcotton yield/acre‡			
150	75	75	0	1833	1406	2568	1936
150	50	50	50	1873	1463	2659	1998
150	30	60	60	2244	1412	2246	1967
120	60	60	0	2045	1646	2671	2120
120	40	40	40	2003	1271	2678	1983
90	45	45	0	1882	1353	1815	1677
90	30	30	30	1780	1426	2344	1852
60	30	30	0	1770	1493	1507	1593
30	15	15	0	1805	1381	1905	1697
0	0	0	0	1796	1284	1237	1439
To compare N-treatment means within irrigation method LSD(0.05)=397.							
To compare N-treatment means between irrigation methods LSD (0.05)=472.							
Irrigation method mean yields					1904	1413	2169

†N application times; PP, preplant; FS, first square; and FF, first flower.
‡Lint yield may be estimated by dividing the seedcotton yield by 3.

COMPARISONS OF FOLIAR NITROGEN FERTILIZATION STRATEGIES AND METHODS FOR COTTON[1]

J.S. McConnell, B.A. Myers, and M. Mozaffari[2]

RESEARCH PROBLEM

Foliar nitrogen (N) fertilization of cotton is a widely used production practice to augment soil-applied N fertilization programs. Producers have used various methods to determine the timing of foliar -N applications, but still raise questions about the validity of foliar fertilization. Reported responses of cotton to foliar fertilization range from no yield response to minimal yield response to significant and economically viable yield increases. The objective of this research was to compare three foliar N- fertilization methods, and determine which of these methods is most likely to produce an increase in yield.

BACKGROUND INFORMATION

Producers fertilize cotton with N to avoid yield loss due to N deficiency. Typically, large amounts of N fertilizer are split-applied, with about half the total amount applied around planting time and the remainder applied before first bloom (Maples et al., 1990). Soil testing for N and the subsequent fertilizer N recommendations may be inappropriate for cotton grown under all production conditions during all years. During years of high yield potential, recommended rates of early-season fertilizer N may be insufficient for maximum yield, and during years of low yield potential, fertilizer N may be over-supplied (Miley, 1982). Previous research has indicated that pre-plant and early sidedress N applications might not meet full-season crop demands. These studies indicated that either soil- or foliar-applied N after first flower may help meet crop N needs and increase yields (Maples and Baker, 1993). These studies and others were also used to develop critical deficiency and sufficiency values of petiole nitrate-N (NO_3-N)

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[2]Associate professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; research specialist, Southeast Branch Station, Rohwer; and research assistant professor, Soil Testing and Research Laboratory, Marianna, respectively.

and incorporated into the Cotton Nutrient Monitoring Program (CNMP, Maples et al., 1992). Foliar fertilization and incorporated into the Cotton of cotton with 23% N (urea) solutions based on CNMP-generated recommendations has been widely practiced by Arkansas cotton producers to meet late-season N requirements (Snyder, 1991).

Recent research indicates that the yield response of cotton to foliar- N applications under current production conditions may not be as dramatic as observed in earlier work (Keisling et al., 1995; McConnell and Baker, 1998). Further, the use of petiole NO_3-N concentration as an indicator of crop N status has been questioned (Heitholt, 1994).

RESEARCH DESCRIPTION

Studies of the responses of cotton to three methods of foliar N fertilization were begun at the Southeast Branch Experiment Station, near Rohwer, Ark. in 2003. Five nitrogen fertilization strategies were compared to an unfertilized control. All plots, except for the unfertilized control, received a recommended, early-season split application of soil-applied N of 100 lb N/acre as urea. Four additional foliar fertilizer-N treatments included: i) Soil-Applied, 30 lb urea-N/acre soil applied at first flower; ii) Foliar-Timed, four weekly scheduled foliar applications of 10 lb N/acre as 23% N solution; iii) Foliar-Cardy, foliar applications of 10 lb N/acre as 23% N solution according to Cardy Meter thresholds (Kenty, et al., 2003); and iv) Foliar-CNMP, foliar applications of 10 lb N/acre as 23% N solution according to the University of Arkansas CNMP recommendations (Maples, et al., 1992). Thus, only two treatments, the unfertilized control and the standard early-season application of 100 lb N/acre did not receive supplemental late-season N applications.

These tests were conducted under furrow-irrigated and dry-land conditions. The cotton variety used was Stoneville 4892 BR. The test was planted on May 12, 2003. The soil at the test site was Hebert silt loam. Selected soil chemical properties are listed in Table 1. Measurements taken on the foliar nitrogen fertilization test included seed cotton yield, plant height, plant population, petiole analysis, and node development information. All the experimental design was a split block with either furrow irrigation or dry-land production as the main blocks. Only yield responses of cotton to the N-treatments are presented in this report.

RESULTS AND DISCUSSION

The 2003 growing season was marred by abnormally wet and cool growing conditions in May and most of June. These inclement conditions were probably responsible for substantial delays in seedling growth and reduced yields. Ponding of water in the irrigated block of this test further exacerbated the weakened condition of the seedlings resulting in lower yields with furrow irrigation than dry-land cotton.

Foliar and soil applications of 23% urea solutions were made periodically during the growing season (Table 2). Foliar treatments were ended in mid-August when large numbers of open bolls indicated the onset of maturity and cut out. The greatest rate of foliar N (six applications totaling 60 lb N/acre) was applied in conjunction with the Cardy Meter analyses (Foliar-Cardy). The least foliar N (three applications totaling 30 lb N/acre) was applied when the CNMP (Foliar-CNMP) was used to trigger foliar fertilization.

Yields were found to significantly differ with the interactive effects of irrigation with the N-fertilization strategy (Table 3). All plots that received N fertilizer produced significantly greater yields than the unfertilized control under both dry-land and furrow irrigation. No other significant differences were observed in yield under furrow-irrigated production conditions. The highest numerical yield under furrow irrigation received only the soil-applied N (100 lb N/acre). No other N-treatment produced significantly greater yields under irrigated conditions.

Dry-land yield responses to the N-treatments were similar to the irrigated results. All dry-land plots that received N-treatments produced yields that were tightly grouped. The greatest yields were produced with foliar-N applications triggered by Cardy Meter (Foliar-Cardy) thresholds (Table 3). Yields from Cardy Meter-triggered treatments were significantly greater than the treatments that only received scheduled (Foliar-Timed) foliar-N applications.

PRACTICAL APPLICATION

The 2003 growing season was the first year of testing and results. More testing is needed before final conclusions are reached. First-year results indicate little yield increase occurred in conjunction with foliar fertilization of cotton with nitrogen.

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Table 1. Residual nitrate-nitrogen (NO_3-N), phosphorus (P), potassium (K), soil pH, and electrical conductivity (EC) to a depth of two feet in six- inch increments from the foliar N-fertilization methods test site in 2003 prior to fertilization.

Depth	No_3-N	P †	K †	pH‡	EC ‡
(inches)	----------(lb/acre)----------				(μS/m)
Irrigated					
0-6	9	123	256	6.9	23
6-12	4	21	240	6.5	17
12-18	4	14	327	5.3	24
18-24	4	14	338	5.2	25
Dry-land					
0-6	17	132	342	5.5	23
6-12	6	34	185	5.6	12
12-18	6	29	207	5.0	19
18-24	9	23	294	4.9	23

†Mehlich-3 extractable (1:7 extraction ratio).
‡Soil pH and EC measured in a 1:2 soil-water mixture.

Table 2. Application dates of supplemental N treatments as triggered by N-fertilization strategy on the foliar N-methods test during 2003.

N-fertilization		Date of foliar or soil fertilization							
Early-season	Late-season	7/9	7/1	7/2	7/3	8/6	8/1	8/1	8/1
(lb N/acre)	(method)								
Irrigated									
100	Foliar CNMP	-[1]	-	-	X	-	X	X	-
100	Foliar Cardy	-	X	X	X	X	X	X	-
100	Foliar timed	-	X	X	X	X	-	-	-
100	Soil applied	X	-	-	-	-	-	-	-
100	0	-	-	-	-	-	-	-	-
0	0	-	-	-	-	-	-	-	-
Dry-land									
100	Foliar CNMP	-	-	X	-	-	X	X	-
100	Foliar Cardy	-	X	X	X	X	X	-	-
100	Foliar timed	-	X	X	X	X	-	-	-
100	Soil applied	X	-	-	-	-	-	-	-
100	0	-	-	-	-	-	-	-	-
0	0	-	-	-	-	-	-	-	-

[1] No application made

Table 3. Seedcotton yields as affected by N-management strategy of the foliar nitrogen methods test during 2003.

N-fertilization		Seedcotton yield[1]		
Early-season	Late-season	Dry-land	Irrigated	N-strategy mean
(lb N/acre)	(method)	----------(lb seedcotton/acre)----------		
100	Foliar CNMP	3265	2769	3017
100	Foliar Cardy	3753	2590	3127
100	Foliar timed	3261	2852	3041
100	Soil applied	3357	2469	2947
100	0	3511	2941	3248
0	0	2844	1699	2272
To compare means within the same irrigation block, LSD (0.05) =489.				
To compare means in different irrigation blocks LSD (0.05) =720.				
Irrigation Method Mean		3325	2540	

[1]Lint yield may be estimated by dividing seedcotton yield by 3.

PHOSPHORUS FERTILIZATION STUDIES FOR COTTON PRODUCTION IN ARKANSAS

M. Mozaffari, N.A. Slaton, J.S. McConnell, E. Evans,and C.E. Kennedy[1]

RESEARCH PROBLEM

Phosphorus (P) plays an important role in cotton (*Gossypium hirsutum* L.) growth and production. Therefore, to maintain balanced plant nutrition and protect the environment, accurate P fertilizer recommendations are required. The objectives of the studies reported here were to evaluate the effect of P fertilization and cotton cultivar on seedcotton yield, and to evaluate the effect of P fertilization on soil properties.

BACKGROUND INFORMATION

In Arkansas, most of the correlation and calibration research supporting cotton P fertilization has been conducted with cultivars that are no longer in use. However, this database is currently the best available scientific information. The research was conducted to provide information to update cotton P fertility recommendation in Arkansas.

RESEARCH DESCRIPTION

Two replicated field experiments were conducted at University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna and a cooperator-grower's field (Parten Farm, Lee County south of Marianna) to assess cotton cultivar and soil response to applications of 0 to 90 lb P_2O_5 /acre broadcast by hand and incorporated. At both sites, standard tillage, pest management, and N and K fertility management practices were followed. At the CBES, two modern cotton cultivars, PayMaster 1218 and Stoneville 4892, were planted. At the Parten Farm, only Stoneville 4892 was planted. Experimental plots were 50-ft long and contained four rows spaced 38 inches apart. The experimental design at the Parten Farm was a completely randomized block with five replications. At the CBES location a completely randomized block design with a split-plot treatment structure was used

[1] Research assistant professor, Soil Testing and Research Lab, Marianna; assistant professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; associate professor, Crop, Soil, and Environmental Sciences Department, Southeast Reasearch and Extension Center, Monticello; farm foreman, Soil Test and Research Laboratory, Marianna; and resident director, Cotton Branch Station, Marianna, respectively.

with cotton cultivar as the main plot factor and P the subplot factor. At both sites, composite soil samples were collected from the 0-to 6-inch depth prior to P fertilizer application and after cotton harvest. Soil samples were extracted with Mehlich-3 (MP3) solution (1:10 ratio) and concentration of elements in the soil extract was measured by inductively coupled plasma atomic emission spectroscopy.

RESULTS AND DISCUSSION

Prior to application of P fertilizer, MP3 extractable P in the top six inches of the two soils was 64 lb P/acre at the CBES and 82 lb P/acre at the Parten field (Table 1). There were no significant cultivar (P =0.05) or cultivar × P interaction (P =0.05) effects on seedcotton yields at CBES. Therefore, yields were averaged across both cultivars. Seedcotton yields were not significantly (P =0.05) increased by P fertilization and ranged from 2631 to 3287 lb/acre suggesting that P deficiency did not limit yield and both cultivars had similar P requirements (Table 2). At the Parten field, seedcotton yields were not significantly affected (P = 0.05) by P fertilization with yields ranging 5271 to 5396 lb/acre. The difference in the seedcotton yields between the two sites was attributed in part to earlier planting and a relatively more favorable soil pH at the Parten site. Similar to the CBES site and despite higher overall yields, seedcotton yield was not limited by P deficiency at the Parten Farm. Since there were no significant cultivar (P = 0.05) or cultivar × P rate (P =0.05) effects at the CBES, soil properties were averaged across both cultivars (Table 3). Application of P rates ≥ 45 lb P_2O_5/acre significantly (P =0.05) increased M3-extractable P in the top six inches of soil at this site. However, the response to increasing P rates was not linear. Although not significant (P =0.05), similar trends were observed at Parten Farm, except that the magnitude of the increase in M3-extractable soil-test P was not as large as the CBES site (Table 4).

PRACTICAL APPLICATION

In these two field experiments, cotton planted in two soils with initial Mehlich-3 (1:10 soil: solution) extractable levels of 64 and 82 lb P/acre did not respond to P fertilization suggesting that seedcotton yields were not limited by P deficiency. Cotton cultivar and cultivar x P rate interaction did not influence the seedcotton yield.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fees.

Table 1. Selected properties from the 0-to 6-inch soil depth for two P fertilization trails at the Cotton Branch Experiment Station (CBES) and the Parten Farm in 2003.

Site	pH†	EC †	OM ‡	NO_3-N§	P¶	K¶	Ca¶	Mg¶
	(μmohs/cm)		-%-	----------(lb/A)----------				
CBES	5.6	24	2.0	6	64	262	2600	564
Parten	7.3	37	1.1	12	82	221	4800	423

† Soil pH and electrical conductivity (EC) measured in a 1:2 (weight: volume) soil-water mixture.
‡ OM, soil organic matter determined by weight loss on ignition.
§ NO_3-N measured by ion- specific electrode.
¶ Mehlich-3 extractable soil nutrients (1:10 extraction ratio).

Table 2. Effects of P fertilizer rate on seedcotton yields at the Cotton Branch Experiment Station (CBES) and the Parten Farm in 2003.

P fertilizer rate	Seedcotton yields	
(lb P_2O_5/A)	CBES	Parten
----------(lb/A)----------		
0	2631	5271
15	2775	5962
30	3193	5668
45	3014	5493
60	3268	5994
90	3287	5396
MSD (0.05)†	NS(946)*	NS (1054)

† Minimum significant difference as determined by Waller-Duncan Test.
*NS= not significant (P=0.05).

Table 3. Effect of P fertilizer rate on post-harvest selected soil chemical properties in the 0-to 6-inch soil depth at the Cotton Branch Experiment Station (CBES) in 2003.

P rate	Soil chemical properties							
	pH†	EC†	OM‡	NO_3-N§	P¶	K¶	Ca¶	Mg¶
lb P_2O_5 / A		(μmohs/cm)	-%-		----------(lb/A)----------			
0	5.9	57	2.5	12	68	367	2450	631
15	5.5	52	2.6	14	60	331	2440	630
30	5.6	53	2.5	15	80	384	2446	613
45	5.9	57	2.5	12	87	384	2610	6558
60	5.7	47	2.5	9	86	357	2414	614
90	5.5	56	2.5	10	89	359	2420	625
MSD(0.05) #	NS	NS	NS	NS	17	NS	NS	NS

† Soil pH and electrical conductivity(EC) measured in a 1:2 (weight: volume) soil-water mixture.
‡ OM, soil organic matter determined by weight loss on ignition.
§ NO_3-N measured by ion-specific electrode.
¶ Mehlich-3- extractable soil nutrients (1:10 extraction ratio).
# Minimum significant difference as determined by Waller-Duncan Test *NS, not significant.

Table 4. Effect of P fertilizer rate on post-harvest selected soil chemical properties in the 0-to 6- inch soil depth at the Parten farm in 2003.

P rate	Soil chemical properties							
	pH†	EC†	OM‡	NO_3-N§	P¶	K¶	Ca¶	Mg¶
lb P_2O_5 / A		(μmohs/cm)	-%-		----------(lb/A)----------			
15	6.7	37	1.0	5	43	295	4092	795
30	6.5	32	1.0	3	43	262	4068	676
45	6.7	40	1.0	4	44	287	4244	747
60	6.7	40	1.7	4	50	270	4039	763
90	6.8	39	1.0	5	47	271	4083	736
MSD (0.05) #	NS*	NS	NS	NS	NS	NS	NS	NS

† Soil pH and electrical conductivity measured in a 1:2 (weight: volume) soil-water mixture.
‡ OM, soil organic matter determined by weight loss on ignition.
§ NO_3-N measured by ion- specific electrode.
¶ Mehlich-3 -extractable soil nutrients (1:10 extraction ratio).
# Minimum significant difference as determined by Waller-Duncan Test *NS, not significant.

IMPROVING COTTON IRRIGATION SCHEDULING IN ARKANSAS

E.D. Vories, P.L. Tacker, and R.E. Glover[1]

RESEARCH PROBLEM

Timely irrigation of cotton has been shown to increase yields, but almost every year producers and researchers observe poor plant development even with irrigation under some condition. Adequate moisture must be present when the cotton crop needs it, but saturated soil conditions deprive the roots of necessary oxygen. Current recommendations lack detail concerning irrigation management. Use of the Arkansas Irrigation Scheduler is recommended; however, the crop water-use function in the Scheduler was not experimentally developed.

BACKGROUND INFORMATION

Cotton was harvested from over 1,000,000 acres in Arkansas in 2001, with almost 65% of those acres irrigated (Arkansas Agricultural Statistics Service, 2002). Published University of Arkansas recommendations (Bonner, 1995) do not include a lot of detail concerning irrigation management. While use of the Arkansas Irrigation Scheduler (Cahoon et al., 1990) is recommended, the crop water-use function (i.e., crop coefficient curve used to predict daily crop water use as a function of crop age) in the Scheduler was not experimentally developed. The original curve was adapted from Supak and Metzer (1977), based on older cultivars and Texas High Plains conditions. Concerns that the curve led to under-estimation of early-season water use led to a modification in 1989.

However, it was felt that the "new" curve was still not closely linked to the development of the cotton crop in Arkansas, so another curve was developed in 1991 and is still in use today. The current curve represented the best estimates of an agricultural engineer (Vories), a cotton physiologist (Oosterhuis), and a cotton breeder (Bourland), but was not experimentally verified. The objective of this research is to validate or develop a new crop co-efficient curve for the Arkansas Irrigation Scheduler.

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[1] Professor, Department of Biological and Agricultural Engineering, Northeast Research and Extension Center, Keiser; agricultural engineer, Cooperative Extension Service, Little Rock; and research specialist, Northeast Research and Extension Center, Keiser, respectively.

RESEARCH DESCRIPTION

A study was conducted at the Northeast Research and Extension Center (NEREC) at Keiser on Sharkey-Steele complex soil to validate the crop water-use function for cotton in the Arkansas Irrigation Scheduler. Subsurface drip irrigation, with tubing placed approximately 12 inches below the original soil surface on 38-inch spacing, was used to precisely control the water applied to plots and Watermark sensors were used to track soil moisture status. The study was designed with split plots within a randomized complete block with four replications. Three levels of irrigation (non-irrigated, NI; 60% of estimated daily ET, Lo; 100% of estimated daily ET, Hi) were the whole-plot treatments and three cultivars (Suregrow 105; PSC 355; DPL NuCOTN 33 B) were the split-plot treatments. The study was planted on May 29, 2003. Daily evapotranspiration was estimated using the system of Cahoon et al. (1990) adapted for subsurface drip irrigation. The drip irrigation system began daily applications on July 3. COTMAN (Danforth and O'Leary, 1998) crop monitoring data were collected throughout the growing season and sequential hand harvests were conducted during the boll-opening period.

RESULTS AND DISCUSSION

Rainfall during the early part of the growing season was sufficient, with over three inches from the May 29 planting through July 1 (Fig. 1). Thereafter until July 27 there were approximately 1.2 additional inches. However, between July 28 and August 4 over four inches of rain were recorded. The number of nodes above white flower (NAWF) peaked <7 on all plots, well below the 9.25 apex of the COTMAN target development curve (TDC). Neither days to NAWF=5, nor days to mean maturity based on sequential hand harvests, were significantly affected by the water treatments or by cultivar (Table 1). The crop was quite late, as demonstrated by the large number of open bolls remaining in the plots.

Similar to NAWF = 5, yield differences were not significant for water treatment or cultivar (Table 2). In fact, irrigation treatment was not significant for lint yield, lint percent, or fiber quality and no irrigation treatment-by-cultivar interactions were observed. Cultivar effects were significant for lint percent and micronaire. Larger differences among the irrigation treatments were expected and were observed in other NEREC cotton studies. However, the differences in water status of the plots were not very large until quite late in the season, as indicated by the estimated soil water deficits (Fig. 2).

PRACTICAL APPLICATION

Irrigation treatment or cultivar did not significantly affect maturity or lint yield in this study. None of the fiber quality parameters had a significant irrigation treatment effect, though lint percent and micronaire had significant cultivar effects.

However, differences in soil water deficits among the treatments were fairly small until very late in the season.

ACKNOWLEDGMENTS

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Table 1. Crop maturity parameters for the 2003 drip irrigation study.

Irrigation treatment	Parameter value			
	SG105	PSC355	NuCOTN 33 B	Avg.*
		NAWF = 5 (DAP)		
NI	74	73	73	74a
Lo	73	73	74	74a
Hi	70	71	73	71a
Avg.*	73a	73a	73a	
		Mean maturity date (DAP)		
NI	134	134	134	134a
Lo	134	133	135	134a
Hi	135	135	135	135a
Avg.*	134a	134a	135a	
		Final % open bolls		
NI	78	75	68	73a
Lo	83	76	67	75a
Hi	77	74	65	72a
Avg.*	79a	75a	67b	

*Means in the same column (irrigation treatment) or row (cultivar) followed by the same letter were not significantly different (P=0.05). No irrigation -by-cultivar interactions observed.

Table 2. Crop yield and quality for the 2003 drip irrigation study.

Irrigation treatment	Parameter value			
	SG105	PSC355	NuCOTN 33 B	Avg.*
		Lint yield (lb/acre)		
NI	748	719	717	728a
Lo	766	809	597	724a
Hi	589	669	642	633a
Avg.*	701a	732a	652a	
		Lint %		
NI	40.8	40.8	38.8	40.1a
Lo	40.6	41.2	38.7	40.2a
Hi	40.8	40.4	38.5	39.9a
Avg.*	40.7a	40.8a	38.7b	
		Micronaire		
NI	4.85	5.35	4.88	5.02a
Lo	5.08	5.22	4.75	5.02a
Hi	5.15	4.90	4.55	4.89a
Avg.*	5.02a	5.16a	4.72b	
		Length (in)		
NI	1.14	1.10	1.12	1.12a
Lo	1.12	1.12	1.10	1.11a
Hi	1.13	1.12	1.13	1.13a
Avg.*	1.13a	1.11a	1.12a	
		Strength (g/tex)		
NI	31.2	31.9	31.1	31.4a
Lo	30.5	31.1	29.6	30.4b
Hi	31.4	32.0	31.3	31.6a
Avg.*	31.0a	31.7a	30.7a	

* Means in the same column (irrigation treatment or row) (cultivar) followed by the same letter were not significantly different (P=.05). No irrigation- by -cultivar interactions observed.

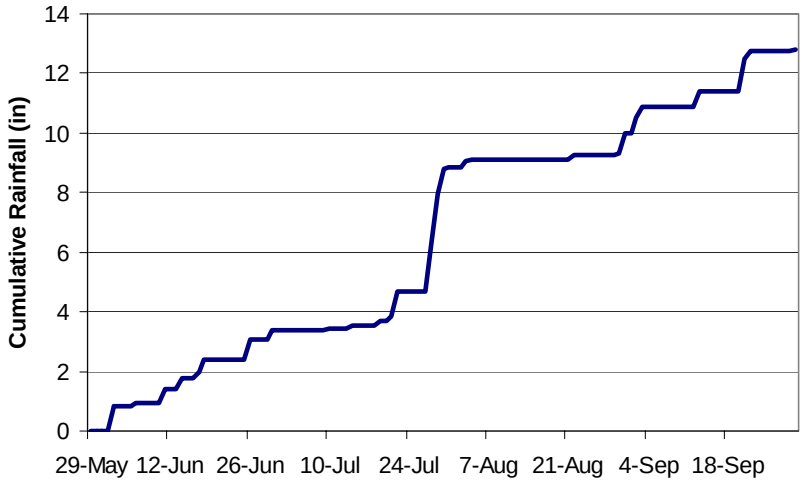

Fig. 1. Cumulative rainfall during the 2003 growing season at NEREC.

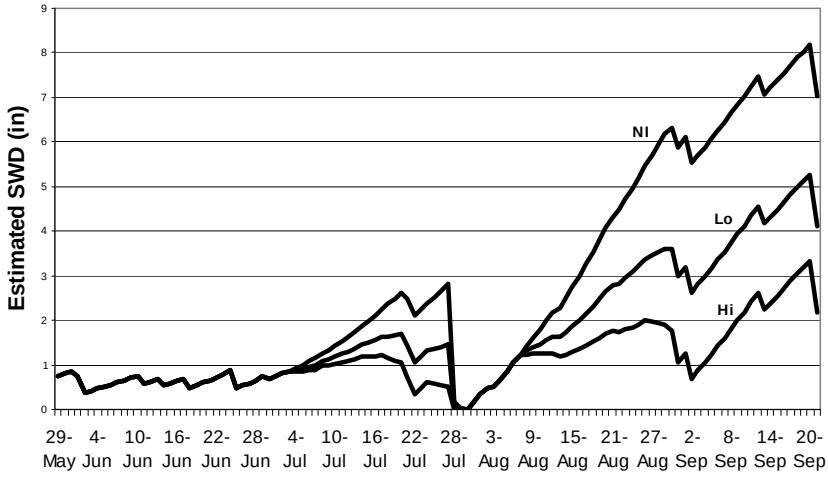

Fig. 2. Estimated soil water deficits from Arkansas Irrigation Scheduler in the 2003 cotton drip irrigation study. N1= non irrigated, Lo=60% estimated daily ET, and H_1=100% of estimated daily ET.

SOIL COMPACTION MODELING IN COTTON

S. Kulkarni[1]

RESEARCH PROBLEM

Soil compaction causes problems for farmers by preventing root growth and development of plants. Compacted soil has smaller pores and fewer natural channels and hence water infiltration is drastically reduced. It causes increased surface wetness, increased runoff and erosion, and longer drying time. Wet fields also delay planting and harvesting, and decrease crop yields. Plant roots experience more resistance to growth in compacted soils, causing inadequate moisture and nutrients absorption by the plant. Plant growth depends on rooting ability, nutrient status, and accessibility of roots to nutrient, soil aeration, and water availability. The objective of the ongoing research are to evaluate the use of soil electrical conductivity data and remote sensing technology for identifying soil compaction levels in the field, and to develop sub-soiling guidelines for cotton production in Arkansas based on the soil electrical conductivity maps and remotely sensed data.

BACKGROUND INFORMATION

Within-field Cone index (CI) provides a measure of soil resistance to penetration. Soil compaction maps and soil electrical conductivity maps have been investigated to explain within-field yield variation. Perumpral (1987) studied soil compaction caused by wheel traffic and tillage operations and concluded that it can cause yield depression within fields. Clark et al. (2000) investigated the use of cone penetrometer data to develop soil strength maps at several different spatial scales. Bakhsh et al. (2000) showed that low yield was influenced by soil and topography and high yield was influenced by topography and management practices. When the cone index value is above 1.4 MPa (200 psi), the soil is considered compacted. It was determined that site-specific subsoiling at a critical CI value of 2 MPa (300 psi), compared to field scale subsoiling, could reduce fuel consumption by 50 % (Fulton et al., 1996). However, it is important to map soil compaction in the field using cost effective and fast methods.

[1] Graduate assistant, Department of Biological and Agricultural Engineering, Fayetteville.

RESEARCH DESCRIPTION

Two cotton fields in Arkansas were chosen for the 2003 experiments; a grower's 160-acre irrigated cotton field in Forrest City and a 1.16 acre, non-irrigated field at the Arkansas Agricultural Experiment Station in Fayetteville. The 1.16 acre field was an experimental field with 16 plots (each four rows wide). It was treated with four tillage treatments; namely Control (no soil disturbance, no-till); Conventional (chisel disked and bedded); Chisel compacted (by running a tractor or a roller), and Compacted with no-till (by running a tractor or a roller to create different levels of compaction). These two fields were harvested on November 1st and 21st, 2003, respectively. In the grower's field at Forrest City, 4 out of the total 7 plots were subsoiled. The general elevation and coordinates were measured with a Global Positioning System (GPS). Soil electrical conductivity for the Forrest City field was measured with Veris, the 2000 Soil EC Mapping System. Soil compaction was measured in both the experimental fields with a digital cone penetrometer (Spectrum Technologies "Field Scout" Model SC900 soil compaction meter, Plainfield, Ill.). Yield was also measured at both fields at harvest.

Remotely sensed spectral data for the Fayetteville field was collected using an EPP2000 spectrometer (Stellar Net Inc., Tampa, Fla.) with wavelength range from 250 to 900 nm. Periodic airborne images of both fields during 2003 growing season were also taken using a four passband Multi-Array Camera developed by Tetracam Inc. (Chatsworth, Calif.).

At Forrest City, a yield monitor was used for yield data collection, whereas at Fayetteville manual yield measurements were carried out. Spatial data layers were generated in ArcView 3.2 and ArcGIS 8.2 using the location information collected using a Leica 500 standard Global Positioning System in Forrest City. In Fayetteville a Trimble TSC1 Asset Surveyor was used for obtaining location information. Linear regression analysis was performed for each field separately to investigate possible statistical links between soil electrical conductivity, cotton yield, and soil compaction.

RESULTS AND DISCUSSION

Higher soil compaction areas exhibited higher soil electrical conductivity at 4, 5, and 6 inches in depth. A strong linear correlation exists between electrical conductivity and mean CI at the depths where the maximum CI existed (CI> 200 psi, $R^2 = 0.92$ at 4 inches, 0.99 at 5 inches, and 0.98 at six inches). The reason for the strong correlation between EC and soil compaction can be supported based on the pore continuity and its effects. Conductivity of electricity in soils takes place through the moisture-filled pores that occur between individual soil particles. Therefore the EC of soil can be influenced by interaction between the pore continuity and soil compaction. The soils in the study area in Forrest City were a Loring silt loam and Arkabulta silt loam. These soils have higher moisture contents. Logically, the soil compaction should normally increase with higher soil EC. Preliminary

results of geographically weighted regression (GWR) analysis showed no statistical significant relationship between soil compaction and yield alone, as the yield depends on a host of parameters such as soil type, irrigation, nutrient management, etc. Classifications of airborne images have shown patterns of yield based on irrigation management and soil types present in the fields.

PRACTICAL APPLICATION

Based on the primary results, we recommend further investigation on a substantial number of cotton fields and compilation of a large dataset on electrical conductivity and soil compaction for analysis. Locating highly compacted areas using soil electrical conductivity maps and classified airborne images may then avoid time-consuming soil sampling and tedious soil compaction measurements, and can be used for site-specific tillage operations. Farmers can use Global Positioning System technology to create customized soil compaction maps using soil electrical conductivity mapping as well.

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GIS AND HYDRAULIC MODELING APPLICATIONS FOR RUNOFF AND SEDIMENT REDUCTIONS IN COTTON

L.G. Stauber, W.H. Baker, and J.M. Worlow[1]

RESEARCH PROBLEM

Compliance of the Clean Water Act of 1972 requires a comprehensive environmental assessment of waterbodies contained within each state to determine if surface-and groundwater meet their designated uses(ADEQ, 2002b). The Arkansas Nonpoint Source Pollution Assessment was conducted for three years on surface waters in the state concluding in 2001. Agriculture was identified as a minor and major source of nonpoint source pollution by causing impairments to 58% of the investigated waterbodies (ADEQ, 2002a). Excessive turbidity and siltation were the predominant deterimental effects of contamination.

BACKGROUND INFORMATION

Sediments, which cause water quality impairments, usually have origins from soil erosion processes. The estimated average annual sheet and rill erosion in Arkansas for 1997 was determined to be 7.8 tons per hectare (USDA, 2000). Similar climatic conditions, land-use management, and topography may all be found in the regional area that includes the Mississippi Delta. Substantial improvements were found using reduced tillage cotton with a cover crop and decreased annual soil losses to 8.91 t ha^{-1} yr^{-1}. Further improvements were demonstrated using no-till cotton production in combination with a cover crop (Fig. 1 and 2). This treatment further decreased soil losses to 0.96 t ha^{-1} yr^{-1}. Appropriate evaluation of watershed areas for the extent of soil erosion and its management may be determined by linking hydraulic models and Geographic Information Systems (GIS) as assessment tools. Raw data for model parameters are directly obtained from published literature, field investigations, or data-layer interpretation. The accuracy of the input data becomes very important in assessing soil erosion (Bartsch et al., 2002). GIS interpretations included as parameter inputs in validated hydraulic models generate results comparable to intensive field studies (Haan et al., 1994).

[1] Seed agronomist, Diana Growseed, Marion; associate professor, and research assistant, Arkansas State University, Jonesboro, respectively.

RESEARCH DESCRIPTION

The Water Erosion Prediction Project (WEPP) watershed model may be used as a management tool for large area assessments. This continuous simulation model is comprehensive by incorporating other submodels to generate a reliable prediction of events. Detailed inputs for this model include: slope, length of slope, cropping system, land use, conservation plans, climate, boundary area, and soil series. Findings of the study had shown the model over -predicted surface runoff by 7.8 and 15.1 % for cropping systems of corn and soybeans, respectively. The mean annual runoff was simulated from an 11-year period. Diversity of watershed area, soil series, and land management was examined for comparative results. WEPP performed very well for the 15 selected sites over a 9-year period.

Slope calculations derived from the three topographical data sources were evaluated using absolute error. The model shows to be useful in situations of varying soil types and topography. WEPP proves to be appropriate for simulating water runoff, erosion and sediment distribution from fields or small watersheds for purposes of erosion assessment and conservation planning.

RESULTS AND DISCUSSION

Each of the 20 cotton fields represented actual production operations used by growers. Decision for this extent of fields was determined from location, availability, and to increase the power of the statistical testing procedures. Accumulative cotton hectares in this study were 1438.03 with a mean of 71.90 ha per field boundary. All investigated fields had a general topographic slope of less than 1 %. The CLIGEN climate component of the WEPP model generated a uniform value of 1278.75 mm yr^{-1} as the average annual precipitation for each field boundary. This represents a 50-year total of 4456 storms produced, 439 rainstorm runoff events, and 159 winter precipitation events produced. This study demonstrated that use of GIS technologies and available remotely sensed databases provided detailed measurements for characterization of the St. Francis watershed study areas. This study also demonstrated that WEPP was sufficiently robust to show differences between BMP effects among varying row-crop production fields and land-management practices.

PRACTICAL APPLICATION

WEPP is designed to be highly sensitive to soil textures. The model accounts for erodibility, infiltration, hydraulic friction factors, rill widths, and sediment transportability. These factors are calculated based on clay, silt, and sand fractions of the soil. Hydraulic friction is the principal factor in the calculation of rill erodibility and sediment transport capacity. This explains the benefits shown

from filter strips and CRP strips. This realistic approach to soil loss complements those field boundaries that have high runoff predictions and low soil losses.

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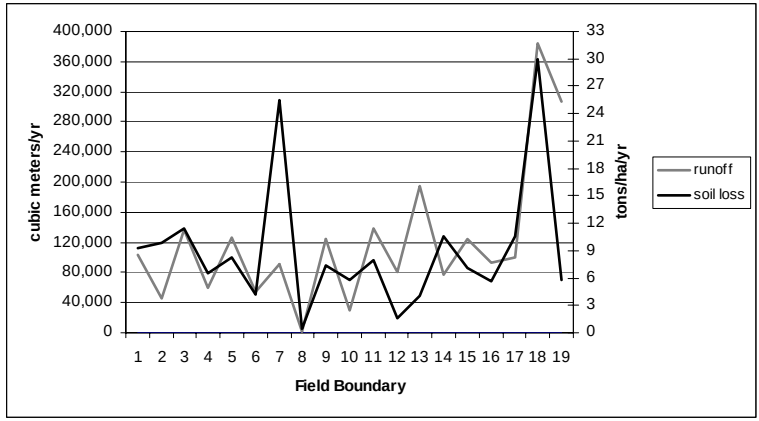

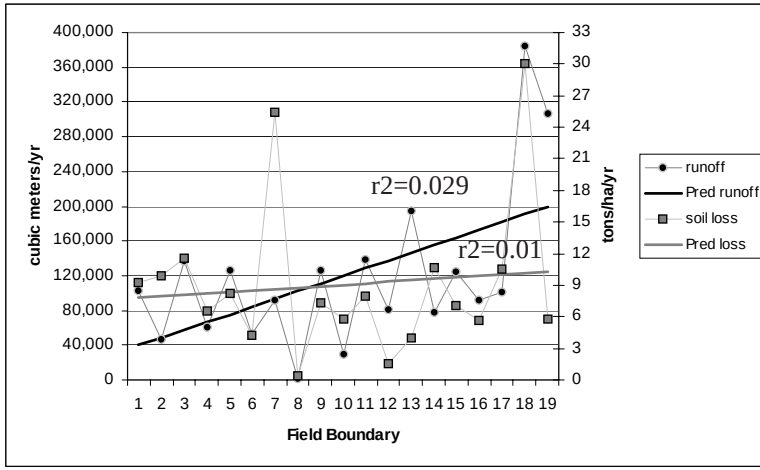

Figs. 1 and 2. Realtionship of WEPP simulated runoff and soil loss mean responses within cotton field boundaries (upper chart). Regression anaylsis was conducted on runoff and soil loss mean responses in cotton field boundaries. Solid lines represent predicted values; data points shown are actual data relative to the predicted values (lower chart).

YIELD AND PETIOLE POTASSIUM LEVELS OF TWO MODERN COTTON CULTIVARS AS INFLUENCED BY POTASSIUM FERTILIZATION

M. Mozaffari, J.S.. McConnell, N.A. Slaton, E. Evans, F. M. Bourland, and C.E. Kennedy[1]

RESEARCH PROBLEM

Proper potassium (K) availability is essential for cotton (*Gossypium hirsutumn* L.) growth and lint development (Coker et al., 2003). In order to improve future K fertilization practices for cotton, a field experiment was conducted to evaluate the effect of K fertilizer application rate on yield and petiole K concentration of two modern cotton cultivars (Stoneville 4892 and Paymaster 1218).

BACKGROUND INFORMATION

The fast fruiting cultivars introduced in the past two decades have different nutritional requirements than the obsolete cultivars that were originally used to develop most of our current K fertilizer recommendations.

RESEARCH DESCRIPTION

A replicated field experiment was conducted at the University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna, Ark., during the 2003 growing season using a completely randomized block design with a split-plot treatment structure, where cotton cultivar was the main plot factor and K rate (0, 30, 30, 60, and 90 lb K_2O/acre) was the subplot factor. Individual plots were 50 ft long and 12.6 ft wide located on a recently leveled parcel of land. Preplant soil pH was 5.4 and Mehlich-3- extractable K was 175 lb/A. Potassium fertilizer treatments were mechanically broadcast and then lightly incorporated by field cultivation. Conventional tillage, pest, and N and P management practices were followed. Cotton was planted on 5 June and harvested on 24 October, 2003. Soil samples were collected prior to K application and after crop harvest and were analyzed by the standard Mehlich-3 procedure. Cotton petiole samples were collected from the 5th node from the top of 20 plants selected randomly and analyzed according to the standard methods of the University of Arkansas.

[1] Research assistant professor, associate professor, assistant professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; farm foreman, Soil Testing and Research Laboratory, Marianna; director, Northeast Research and Extension Center, Keiser; and resident director, Cotton Branch Station, Marianna, respectively.

RESULTS AND DISCUSSION

Statistical analysis of seedcotton yields, petiole K concentrations, and post-harvest soils data indicated that there was no significant cultivar or cultivar × K rate (interaction) effects. Therefore, data were averaged across cultivars. Pre-application soil-test K was 175 lb K/acre, where a response to K fertilization was expected. Seed-cotton yields ranged from 1180 to 1720 lb/acre and were not significantly (P =0.05) affected by K fertilizer rate (Table 1). The lack of a significant yield response to K fertilization was somewhat unexpected since according to current recommendations a yield response to K fertilization is anticipated when soil-test K is <350 lb K/acre. A number of factors may have contributed to lack of response to K fertilization, including late planting and low initial soil pH. Petiole K concentrations were generally below the critical K levels currently in use by the University of Arkansas (Table 2). Petiole K concentrations were not affected by K application rate early in the season, and were significantly different only on 20 August. Petiole K concentrations on 20 August tended to increase as early-season K rate increased, although the petiole K concentrations were always below the established sufficiency level of 3.5 percent. Post-harvest soil-test K in the surface and subsurface horizons wAS not affected by K application rate. Soil-test K in the 0- to 6-inch depth ranged from 249 to 267 lb K/acre (Table 3), suggesting that, in this experiment even after K fertilization, K deficiency may have limited seed-cotton yields. Perhaps the lower yield potential of late-planted cotton also reduced the K nutritional requirements of cotton for achieving its maximum yield potential. This is consistent with the petiole K data where the K concentrations were generally below the current sufficiency levels (Table 3).

PRACTICAL APPLICATION

The two modern cotton cultivars tested in this experiment had similar K requirements. Potassium fertilizer application failed to increase cotton yields regardless of cotton cultivar, despite an initial soil-test K concentration that was below the level considered as optimum. Petiole K concentrations were also below the current sufficiency levels throughout the season, regardless of the K fertilizer application rate.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fees.

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Table. 1 Effect of K fertilizer rate, averged across cultivars, on seedcotton yield at the Cotton Branch Experiment Station (CBES) in 2003.

K-fertilizer rate	Seedcotton yield
lb K_2 0/a	lb/A
0	1570
30	1720
30+60 †	1180
60	1370
90	1520
MSD (0.05) ‡	NS

† 30 lbs K_2O/acre applied before planting and 60 lb K_2O/acre on 12 September.
‡Minimum Significant Difference as determined by Waller-Duncan Test.

Table 2. Effect of K fertilizer rate, averaged across cultivars, on cotton petiole K concentration in 2003.

K-fertilizer rate	7 August	14 August	20 August	28 August
	FF-1	FF+1	FF+2	FF+3*
lb K_2O/A	----------Petiole K(%)----------			
0	2.8	2.9	1.6	1.8
30	3.2	2.7	1.7	2.0
30+60 †	2.6	2.0	1.3	1.8
60	3.3	2.8	1.8	2.3
90	3.4	2.9	2.6	2.4
MSL ‡	4.0	4.0	3.5	3.0
MSD at 0.05 §	NS	NS	0.8	¶

†30lb K_2O/acre applied before planting and 60 lb K_2O/acre on 12 September.
‡ (MSL)Published by Snyder et al., 1995.
§ Minimum significant difference (MSD) as determined by Waller-Duncan test, NS= not significant.
¶ Unable to perform statistical analysis due to loss of samples.
*FF= first flower, FF-1=one week before FF, FF+1= one week after FF, FF+2= two weeks after FF, and FF+3= three weeks after FF.

Table 3. Effect of K fertilizer rate on surface (0 to 6 inch) and subsurface (6 to 12 inch) post-harvest soil-chemical properties.

K fertilizer	pH†		EC†		OM‡		NO_3-N§		P¶		K¶		Mg¶	
lb K_2O_5 / A			(μmohs/cm)		-%-		----------(lb/A)----------							
rate	0-6	6-12	0-6	6-12	0-6	6-12	0-6	6-12	0-6	6-12	0-6	6-12	0-6	6-12
0	5.3	5.3	42	31	1.3	1.2	6.8	5.9	53	47	253	266	686	663
30	5.3	5.0	36	33	1.3	1.3	6.8	6.1	53	49	249	237	633	625
30+60#	5.1	4.8	42	39	1.3	1.2	4.6	4.9	52	47	267	241	757	767
60	5.1	5.0	44	33	1.3	1.2	5.9	5.8	54	47	267	241	757	767
90	5.0	4.9	43	32	1.3	1.1	4.0	3.9	51	46	267	231	734	728
MSD at 0.05*	NS	0.5	NS	7	NS	0.1	NS	NS	NS	NS	NS	NS	NS	NS

†Soil pH and electrical conductivity (EC) measured in a 1:2 (weight:volume) soil-water mixture.

‡ OM, soil organic matter determined by weight loss on ignition.

§ NO_3-N measured by ion specific electrode.

¶ Mehlich-3-extractable soil nutrients (1:10 extraction ratio).

30 lbs K_2O/ acre applied before planting and 60 lbs K_2O/ acre on 12 September.

* Minimum Significant Difference as determined by Waller-Duncan Test NS= not significant.

CRITICAL PETIOLE POTASSIUM LEVELS AS RELATED TO PHYSIOLOGICAL RESPONSES OF CHAMBER-GROWN COTTON TO POTASSIUM DEFICIENCY

D.L. Coker, D.M. Oosterhuis, M. Arevalo, and M. Mozaffari[1]

RESEARCH PROBLEM

Throughout the growing season, potassium (K) plays a critical role in cotton (*Gossypium hirsutum* L.) nutrition, yield, and fiber quality. The effect of K deficiency on plant growth and physiological processes during early reproductive growth needs additional investigation in order to develop K fertility management practices for modern fast-fruiting cotton cultivars. Our study objective was to investigate the effect of K deficiency on growth, physiology, and K partitioning to determine the critical K concentration in petioles of uppermost fully expanded main-stem leaves of growth chamber-grown cotton.

BACKGROUND INFORMATION

The nutritional status of the cotton plant can be determined during the growing season with dependable accuracy by petiole sampling (Robertson et al., 2002). Early detection of pending and perhaps sporadic K deficiencies in cotton is crucial to avoid loss of yield and decreased fiber quality (Oosterhuis, 1995). However, a good understanding of when and which physiological processes are first affected by declining K concentrations in petioles during and after the onset of reproductive growth is important for correcting pending K deficiencies.

RESEARCH DESCRIPTION

Seeds of 'Suregrow 215BR' cotton were planted on 8 August 2003 in 50, 4-L pots filled with washed sand. Plants were nurtured with half-strength Hoagland's solution for optimal moisture and nutrients. Growth chamber environmental conditions were adjusted to a 12-hour photoperiod with day/night temperatures of 30/25°C, humidity of 60/80%, and the CO_2 concentration in the growth chamber was kept at ambient levels. To establish treatments, approximately

[1]Research specialist, distinguished professor, graduate assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville; research assistant professor, Soil Testing and Research Lab, Marianna, respectively.

21 days after planting, the pots were divided into two groups of 25 each. Half of the pots received half-strength complete Hoagland's solution, which contained 3 mM of K (plus K treatment), and the other half of pots received a K-free, half-strength Hoagland's solution (minus K treatment). The pots were arranged in a completely randomized block design with five replications of each treatment for each of the planned five weekly harvests. A more complete description of methodology for this type of study was published by Bednarz and Oosterhuis (1999). There were five weekly harvests following the establishment of K treatments. The following were measured at each of the five weekly harvests: photosynthesis, stomatal conductance, chlorophyll, and temperature of uppermost fully expanded main-stem leaves, air temperature, dry-matter partitioning between above-and below-ground organs and nutrient concentration in all harvested organs.

RESULTS AND DISCUSSION

The earliest indicators of K deficiency stress were observed in lower-stomatal conductance ($P \leq 0.05$) and less leaf cooling ($P \leq 0.1$) in the uppermost unfolded (fourth-node) leaves at 14 days after treatment establishment (DATE) (Fig.1). Stomatal conductance ($P \leq 0.05$) was reduced in K-deficient compared to K-sufficient leaves at 14 DATE while photosynthesis ($P \leq 0.05$) and leaf cooling ($P \leq 0.1$) were reduced in K-deficient compared to K-sufficient leaves at 21 DATE (Fig.1 and 2, respectively). At 28 DATE, photosynthesis ($P \leq 0.05$), chlorophyll a ($P \leq 0.01$), and chlorophyll b ($P \leq 0.05$) were lower in K-deficient compared to K-sufficient leaves (Figs. 1 and 3, respectively). At each harvest interval, we analyzed K in the fourth-node petioles. Beginning at 7 DATE and at each harvest interval thereafter, petiole K concentrations were lower ($P \leq 0.05$) in the minus-K compared to plus-K treated plants (Fig. 4). The decreases in petiole nitrate concentration at 14 DATE coincided with significant decreases in plant physiological growth parameters (e.g. gas exchange), which indicated critical concentrations of petiole nitrate.

PRACTICAL APPLICATION

Decreased stomatal conductance and less leaf cooling were two of the earliest physiological indicators of the onset of K deficiency. The reduction in leaf photosynthesis beginning at 14 DATE corresponded well with reductions in plant growth, i.e., leaf area and biomass accumulation (Oosterhuis et al., 2003). By 21 DATE, stomatal conductance and photosynthesis of the fourth-node leaves were significantly lower due to K deficiency; therefore less photoassimilates and energy were available for vegetative and reproductive growth. Based on our physiological measurements, the critical level of K concentration in fourth-node petioles would be between 1.65 to 2.12 %. Verification of the consistency of these results in future field tests will provide valuable information for in-season management of

K nutrition for cotton production in Arkansas. These results will improve our understanding of expected K concentration values in uppermost unfolded leaf petioles for cotton between the onset of the reproductive stage and peak bloom.

ACKNOWLEDGMENTS

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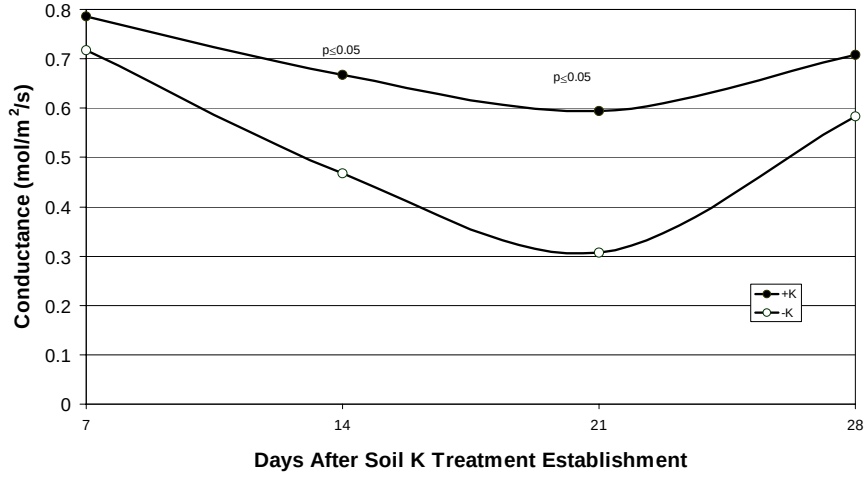

Fig. 1. Effect of K deficiency on fourth-node leaf conductance (top) and leaf cooling (bottom) of chamber-grown cotton.

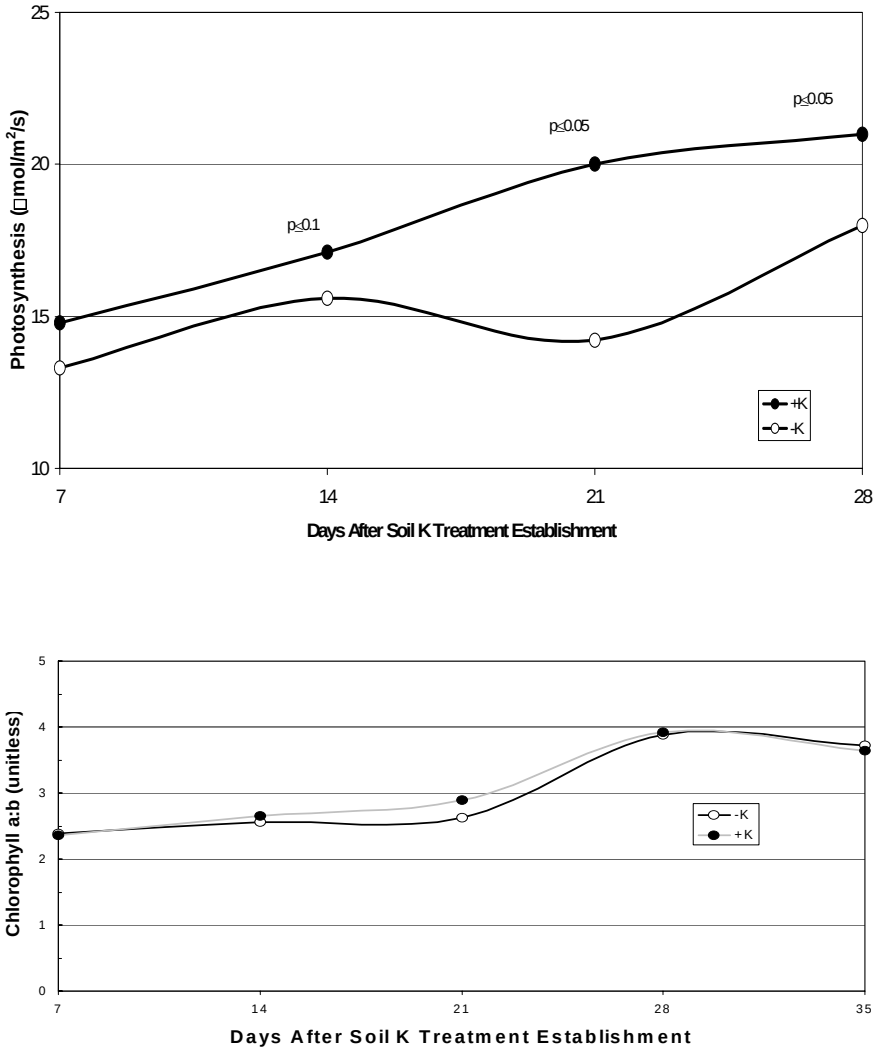

Fig. 2 Effect of K deficiency on photosynthesis of the fourth-node leaf of chamber-grown cotton.

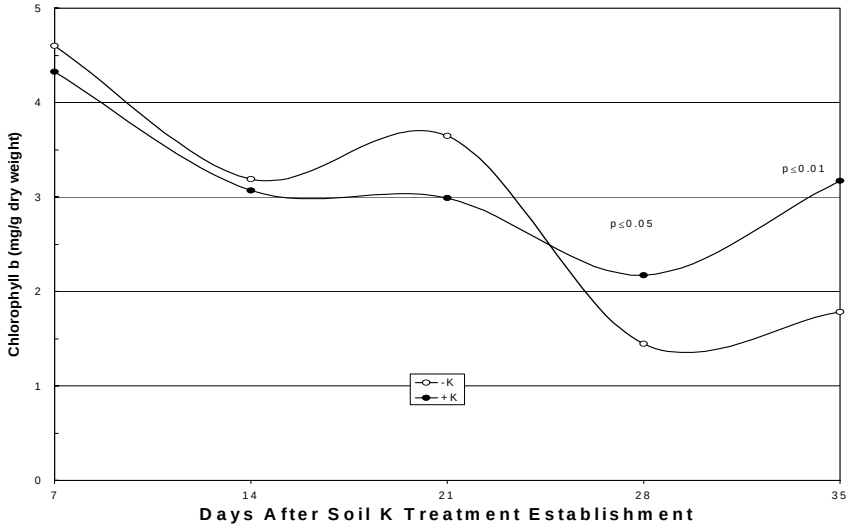

Fig. 3. Effect of K deficiency on fourth-node leaf chlorophyll a (top) and chlorophyy b (bottom) of chamber-grown cotton. Fayetteville, 2003.

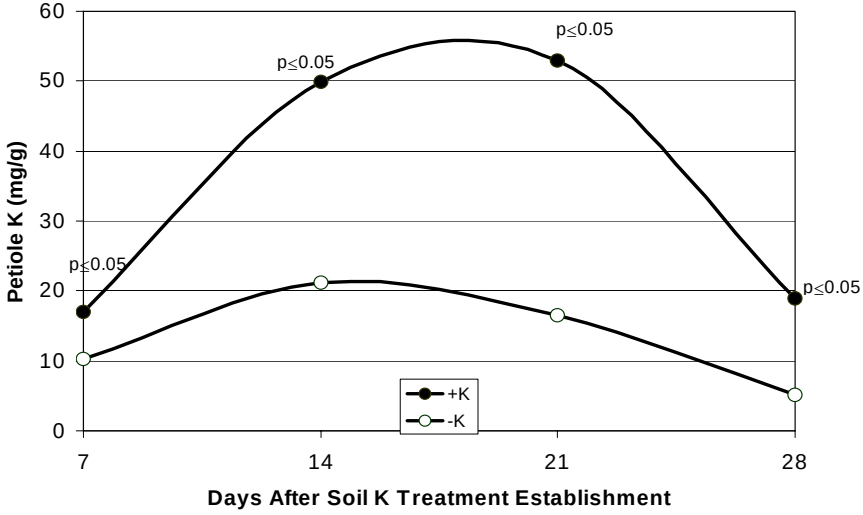

Fig. 4. Effect of K deficiency on fourth-node petiole-K concentration of chamber-grown cotton. Fayetteville, 2003.

THE PHYSIOLOGICAL RESPONSE OF COTTON TO HIGH TEMPERATURES FOR GERMPLASM SCREENING

A.C. Bibi, D.M. Oosterhuis, R.S. Brown, E.D. Gonias, and F.M. Bourland [1]

RESEARCH PROBLEM

There is major concern about year-to-year variability in cotton yields. Even though yield is mainly controlled by genetics, environment, and cultural inputs, it is now believed that temperature is one of the major factors affecting the development of cotton yield and therefore yield variability. Our earlier work has indicated a strong negative correlation between high temperatures and low cotton yields in Arkansas. However, there is limited information on the effects of high temperature on the physiology and growth of cotton. In this study, it was hypothesized that differences in response to high temperatures exist within the current cultivars and even moreso in diverse germplasm lines.

BACKGROUND INFORMATION

Yield is controlled by genetic and environmental factors as well as by cultural inputs. Of these, it is thought that environmental factors exert the major influence on yield development during the season. Researchers have suggested that changes in cotton germplasm over the past thirty years may have resulted in reduced tolerance of modern cultivars to environmental stress (Lewis et al., 2000; Brown and Oosterhuis, 2004). However, our earlier research has indicated that high temperature is the major factor adversely affecting cotton yields during the season and that a strong negative correlation exists between high temperatures and low cotton yields in Arkansas (Oosterhuis, 2002). The ideal temperature range for cotton is 68 to 86^{o}F (20 to 30^{o}C) (Reddy et al., 1991) with an optimum for photosynthesis being 82^{o}F (28^{o}C) (Burke et al., 1988). However, average maximum temperatures during boll development in the Mississippi Delta are almost always well above these optima. Improved tolerance of cotton germplasm is obviously needed to stabilize yields for consistent high yields. Gipson and Joham (1969) documented cotton yield response to high temperature, but research about the physiological response of the cotton plant to high temperature is limited.

[1] Graduate assistant, distinguished professor, graduate assistant, graduate assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville, and director, Northeast Research and Extension Center, Keiser, respectively.

The objective of this study was to use techniques identified in a companion study to screen a select set of diverse cotton germplasm for tolerance to high temperature stress.

RESEARCH DESCRIPTION

A field study was planted at the University of Arkansas Agricultural Research and Extension Center in Fayetteville, Ark., in May 2003, on Captina silt loam (Typic fragiudult). This study was conducted to evaluate temperature tolerance in eight cotton genotypes, four modern and four obsolete with similar parenting, using a Randomized Complete Block design with six replications. The modern cultivars evaluated were ST 474, SG 747, DP 33B, and Acala Maxxa, and the obsolete cultivars used were ST 213, REX, DP 16, and SJ2. During the experiment temperature data were collected and measurements were taken within a temperature range of 28 to 32°C after the plants had entered the pinhead square stage. Measurements were made of total active proteins (using the Bradford method); membrane leakage (using leaf-discs placed in 2 ml ionized water for 48 hours and measuring conductivity with an Automatic Seed Analyzer); chlorophyll fluorescence (using a Modulated Chlorophyll Fluorometer OS1-FL);antioxidant enzymes (using the technique of Anderson et al., 1992,); and polyols (using HPLC).

RESULTS AND DISCUSSION

Significant differences between the genotypes were observed mostly at the higher temperatures, above 30.5°C (Fig. 1, 2, 3). Unfortunately, extremely high temperatures were not experienced in this study. Measurements of sugar alcohols (Polyols) as an indication of stress response to temperature showed clear genotypic differences (Fig. 4). Old cultivars appeared to exhibit a greater increase in polyols at higher temperatures. Only the two Acala cultivars showed decreased polyols at higher temperatures.

MODERN VERSUS OBSOLETE CULTIVARS

Preliminary field data showed significant differences between the obsolete and modern cultivars only at 30.5°C for fluorescence and total active proteins. Chlorophyll fluorescence (Fig. 5) showed significant differences between old and new cultivars at 30.5°C, with the old cultivars experienced lower fluorescence than the new. This indicates that the obsolete cultivars suffer from more stress than the new cultivars at that temperature. At the higher temperature, the old cultivars showed higher fluorescence than the modern cultivars, which we are not able to explain. The same results were confirmed by measuring total active proteins (Fig.

6) for quantifying temperature tolerance. No significant differences were observed for membrane leakage, antioxidant enzymes, and polyols showing that there was similar response to temperature for both obsolete and modern cultivars (data not presented).

PRACTICAL APPLICATION

Selection of a diverse collection of old and new cotton genotypes has permitted initial screening for temperature tolerance using techniques identified in a companion study. Results showed significant differences between the obsolete and modern cultivars only at 30.5°C for chlorophyll fluorescence and total active proteins. No significant differences were observed for membrane leakage, antioxidant enzymes, and polyols showing that there was similar response to temperature for both obsolete and modern cultivars. This study will be continued in 2004.

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Reddy, V.R., D.N. Baker, and H.F. Hodges. 1991. Temperature effect on cotton canopy growth, photosynthesis, and respiration. *Agronomy Journal* 83:699-704.

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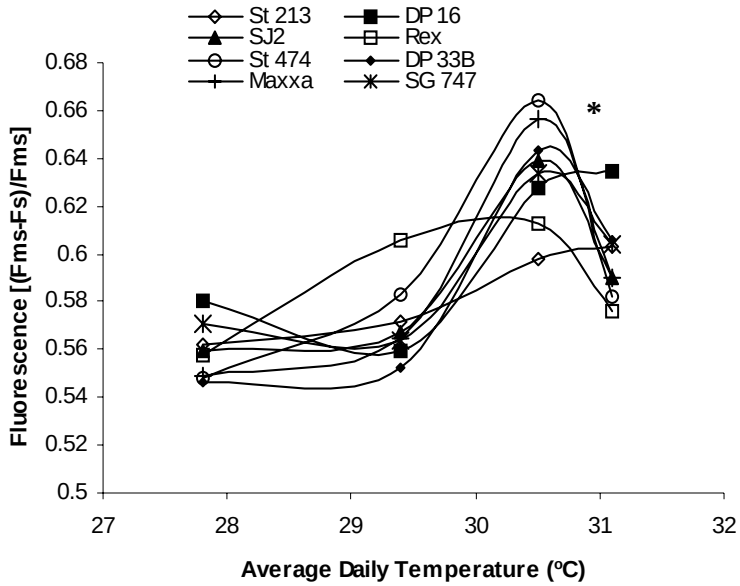

Fig. 1. Field evaluation of genotype responses to temperature as measured using chlorophyll fluorescence. * Indicates that between the cultivars there were significant differences (P=0.05).

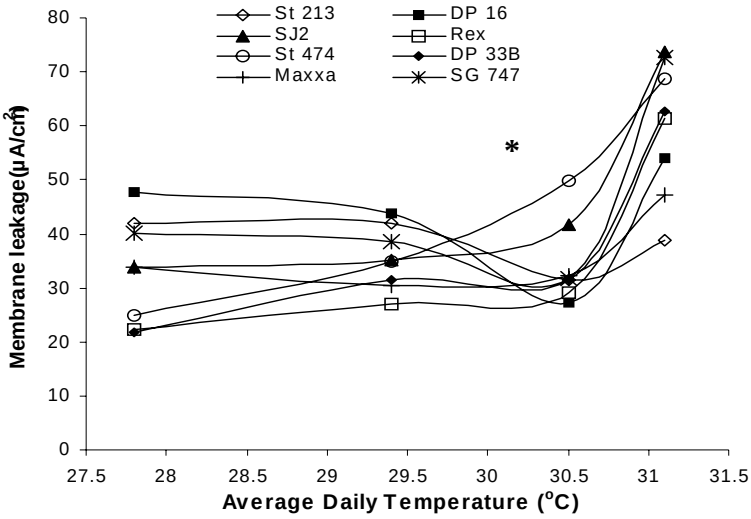

Fig. 2. Field evaluation of genotypic responses to temperature as measured using membrane leakage. -*Indicates that between the cultivars there were significant differences (P=0.05).

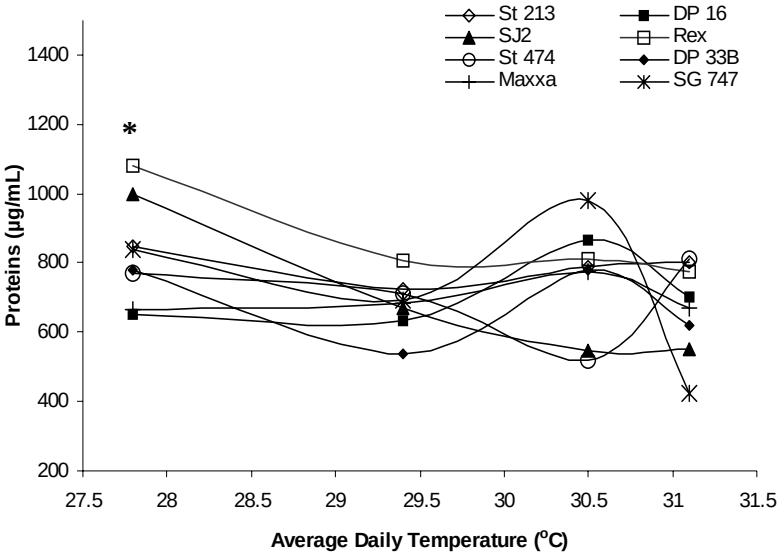

Fig. 3. Field evaluation of genotypic responses to temperature as measured using total protein content.* Indicates that between the cultivars there were significant differences (P=0.05).

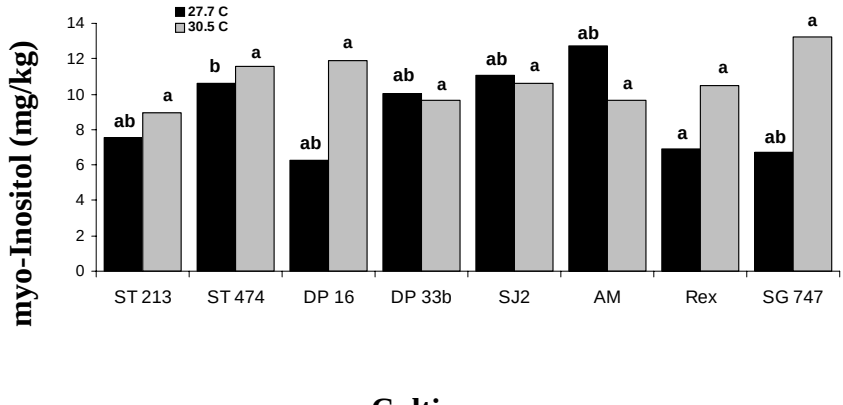

Fig. 4. Genotypic differences in polyols (myo-inositol) at two temperatures Columns with the same letter are not significantly different (P=0.05).

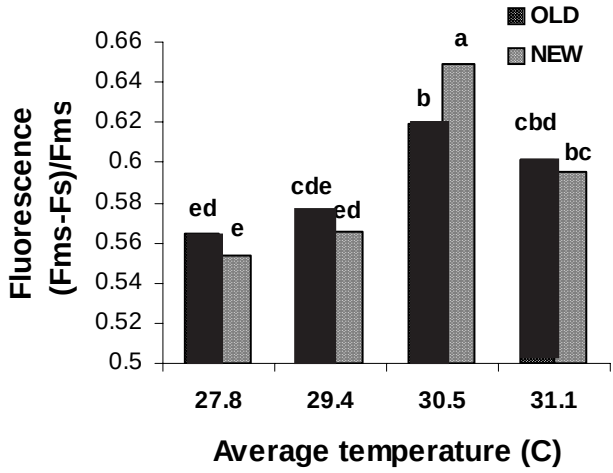

Fig. 5. Effect of high temperature on chlorophyll fluorescence of obsolete and modern cultivars. Columns with the same letter are not significantly different (P=0.05).

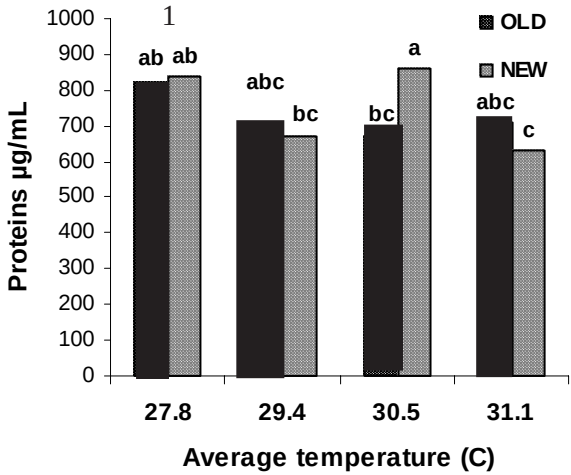

Fig. 6. Effect of high temperature on total active proteins of obsolete and modern cultivars. Columns with the same letter are not significantly different (P=0.05).

EVALUATION OF DIFFERENT TECHNIQUES FOR QUANTIFYING THE PHYSIOLOGICAL RESPONSE OF COTTON UNDER HIGH TEMPERATURES

A.C. Bibi, D.M. Oosterhuis, E.D. Gonias, and F.M. Bourland[1]

RESEARCH PROBLEM

Extreme variability in cotton (*Gossypium hirsutum* L.) yields from year to year, as well as a lack of any noticeable increases in yield over the past decade, has caused major concern for producers. Although yield is mainly controlled by genetics, environment, and cultural inputs, it is now believed that temperature is one of the major factors affecting the development of cotton yield. Our earlier work has indicated a strong negative correlation between high temperatures and low cotton yields in Arkansas. However, there is limited information on the effects of high temperature on the physiology and growth of cotton. In this study, it was hypothesized that numerous physiological and biochemical parameters will be affected by elevated temperatures, but only a few of these will be both sensitive to high temperatures and easy to measure in large breeding trials.

BACKGROUND INFORMATION

Unpredictable year-to-year variability in cotton yields and stagnation of yields are major concerns of the cotton industry. Yield is controlled by genetic and environmental factors as well as by cultural inputs. Of these, it is thought that environmental factors exert the major influence on yield development during the season. Researchers have suggested that changes in cotton germplasm over the past thirty years may have resulted in reduced tolerance of modern cultivars to environmental stress (Lewis et al., 2000; Brown and Oosterhuis, 2004). However, our earlier research has indicated that high temperature is the major factor adversely affecting cotton yields during the season and that a strong negative correlation exists between high temperatures and low cotton yields in Arkansas (Oosterhuis, 2002). The ideal temperature range for cotton is 68 to 86^{o}F (20 to 30^{o}C) (Reddy et al., 1991) with an optimum for photosynthesis being 82^{o}F (28^{o}C) (Burke et al., 1988). However, average maximum temperatures during boll development in the Mississippi Delta are almost always well above these optima. Improved tolerance

[1] Graduate assistant, distinguished professor, graduate assistant, graduate assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville; and director, Northeast Research and Extension Center, Keiser, respectively

of cotton germplasm is obviously needed to stabilize yields for consistent high of cotton germplasm is obviously needed to stabilize yields for consistently higher yields. Gipson and Joham, (1969) documented cotton yield response to high night temperature, but research about the physiological response of the cotton plant to high day temperature is limited. The first step is to find a reliable and practical technique to measure temperature tolerance in cotton, so as to be able to use this in breeding efforts to improve temperature tolerance in cotton.

RESEARCH DESCRIPTION

Two studies were conducted in May 2003 in growth chambers in the Altheimer Laboratory, Fayetteville, Arkansas. In the first growth-chamber study, four different fluorometer techniques were evaluated. Cotton (*Gossypium hirsutum* L.) cv. Stoneville 213 and 474 were planted in 2L pots filled with Sunshine mix and watered with half-strength Peter's nutrient solution. The growth chamber was maintained at 30°F/20°C (day/night) temperatures, at 80% relative humidity, and with 12h photoperiods. Measurements were started at the pinhead square stage using the fourth main-stem leaf. Fluorescence was measured using the light-adapted test (using a fluorometer with a light-adapted clip); the dark-adapted test 1 (using the dark-adapted clip); the Leaf-tissue technique (using leaf punches 1.5 cm in diameter placed in a moistened environment and fluorescence measured with the dark-adapted test); and the dark-adapted test 2 (using a fluorometer with a dark-adapted clip on leaves covered with black bags). In the second growth-chamber study different techniques for quantifying temperature tolerance were evaluated under elevated temperatures. Cotton (*Gossypium hirsutum* L.) cv. Suregrow 747 was planted in Sunshine mix and watered with half-strength Peter's nutrient solution.

The plants were maintained at 30°F/20°C until the pinhead square stage, after which they were divided into two sets and half moved to 35/30°C. After three days at this temperature regime the temperature was raised to 40/30°C. Measurements were taken four days after the plants were placed in the elevated temperature, using the fourth main-stem leaf from the terminal. Measurements were made of total active proteins (Bradford, 1976); membrane leakage (using leaf-discs placed in 2 ml ionized water for 48 hours and measuring conductivity with an Automatic Seed Analyzer); chlorophyll fluorescence (Modulated Chloropohyll Fluorometer OS1-FL); and antioxidant enzymes (Anderson et al., 1992).

RESULTS AND DISCUSSION

Evaluation of Different Fluorometer Techniques

The statistical analysis of the results (Fig. 1) showed that the light-adapted test and the dark-adapted test 2 had consistent results with no significant differences

among the measurements. The dark-adapted test 1 and the leaf–tissue techniques showed significant differences among their measurements. This can be explained by the fact that the tissue in both techniques did not have time to adapt to the dark conditions. Therefore, the tissue was still under light conditions during the first measurement (0 min) and the Fv/Fm values were lower. The light-adapted test was significantly different compared with the other techniques. In conclusion all four fluorometer techniques showed consistent measurements of chlorophyll fluorescence with time. However, the light-adapted test was more practical, reliable, and potentially more easy to use in the field.

Evaluation of Different Techniques under Elevated Temperatures

The preliminary study with contrasting temperatures determined that 3-4 days were needed at a particular elevated temperature before plant metabolic responses could be detected; i.e. by membrane leakage (ML), fluorescence (FL), proteins (PR), and catalase (CAT). Among these four measurements (Fig. 2) the results showed that ML and CAT were the most sensitive and accurate methods for quantifying temperature tolerance (Table 1). Membrane leakage was the most sensitive technique tested in a comparison study for quantifying temperature tolerance in the field. Fluorescence also showed some sensitivity for quantifying temperature tolerance with the advantage that it is a much easier technique for field use. Similarly catalase activity was sensitive but time-consuming and more appropriate for laboratory analysis.

PRACTICAL APPLICATION

Given the urgent need to identify cotton genotypes with temperature tolerance, this study evaluated techniques to quantify plant response to high temperatures. Membrane leakage was the most sensitive technique tested while fluorescence also showed some sensitivity for quantifying temperature tolerance. Furthermore, measurement of the activity of the enzyme catalase was very sensitive but very time consuming. The results will be used for screening cotton germplasm to identify lines to be used in plant breeding for improving cotton response to high temperature for more efficient production and stable yields.

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Reddy, V.R., D.N. Baker, and H.F. Hodges. 1991. Temperature effect on cotton canopy growth, photosynthesis and respiration. *Agronomy Journal* 83:699-704.

Oosterhuis, D.M. 1999. Yield response to environmental extremes in cotton. Pp 30-38. *In:* D.M. Oosterhuis (ed.). Proceedings 1999 Cotton Research Meeting and Summaries of Research in Progress. Ark. Agri. Exp. Sta., *Special Report* 193.

Table 1. Contrasting sensitivity of techniques on elevated temperatures.

	Measurements			
Temperature treatment	Fluorescence	Membrane leakage μA/cm^2	Proteins μ g/mL	Catalase mM/g
30°C	0.76 a †	21.4b	1301.2a	1702.4a
35°C	0.778 a	28.8a	1038.6b	1761.2a
% of control ‡	102.4	134.5	79.82	103.5
30°C	0.771a	34.7b	1011.5a	1274.1a
40°C	0.393b	101.1a	763a	255.3b
% of control	50.96	291.6	75.4	20.03

† Numbers in a column followed by the same letter are not significantly different

‡ ($P \leq 0.05$). The higher temperature as a percentage of the 30°C.

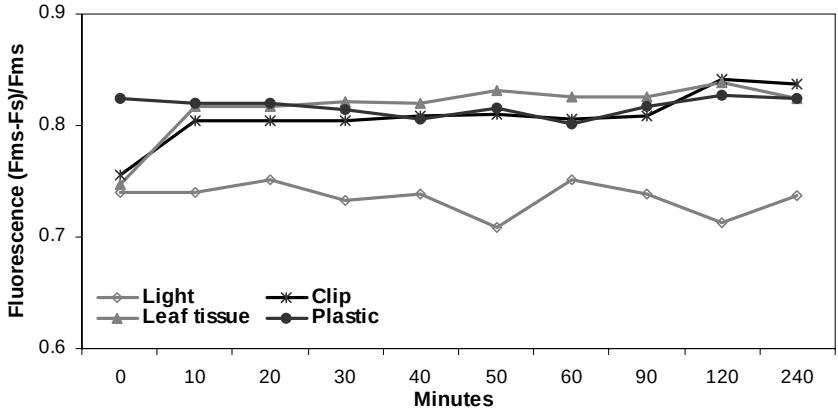
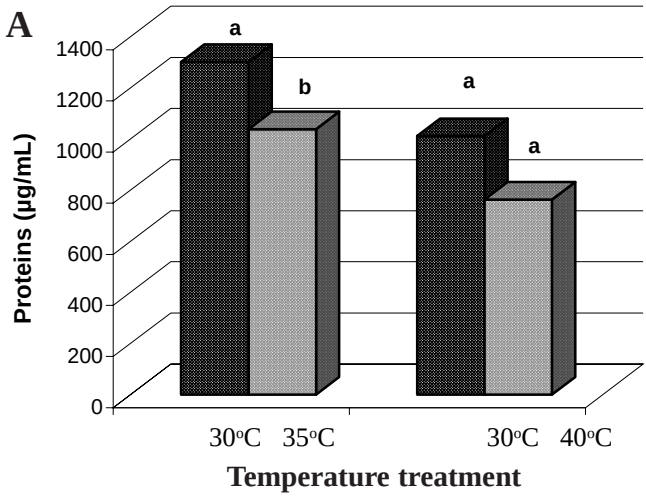
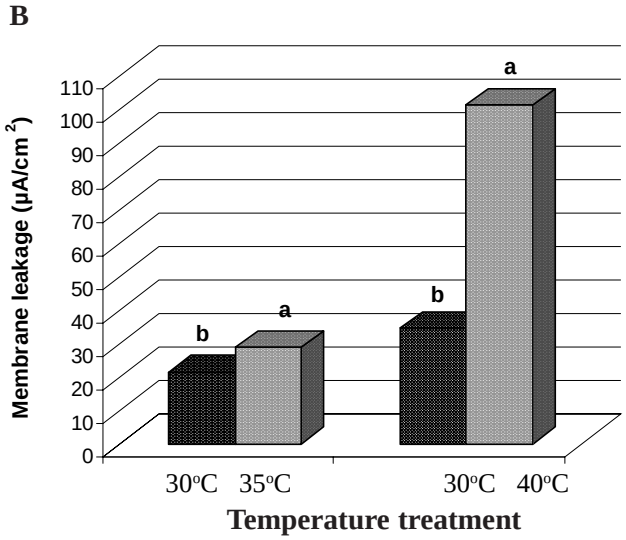


Fig. 1. Evaluation of four fluorometer techniques under stable condition at 30°C only.


A
Proteins (µg/mL)
1400
1200
1000
800
600
400
200
0
a
b
a
a
30°C 35°C
30°C 40°C
Temperature treatment


B
Membrane leakage (µA/cm 2)
110
100
90
80
70
60
50
40
30
20
10
0
b
a
b
a
30°C 35°C
30°C 40°C
Temperature treatment

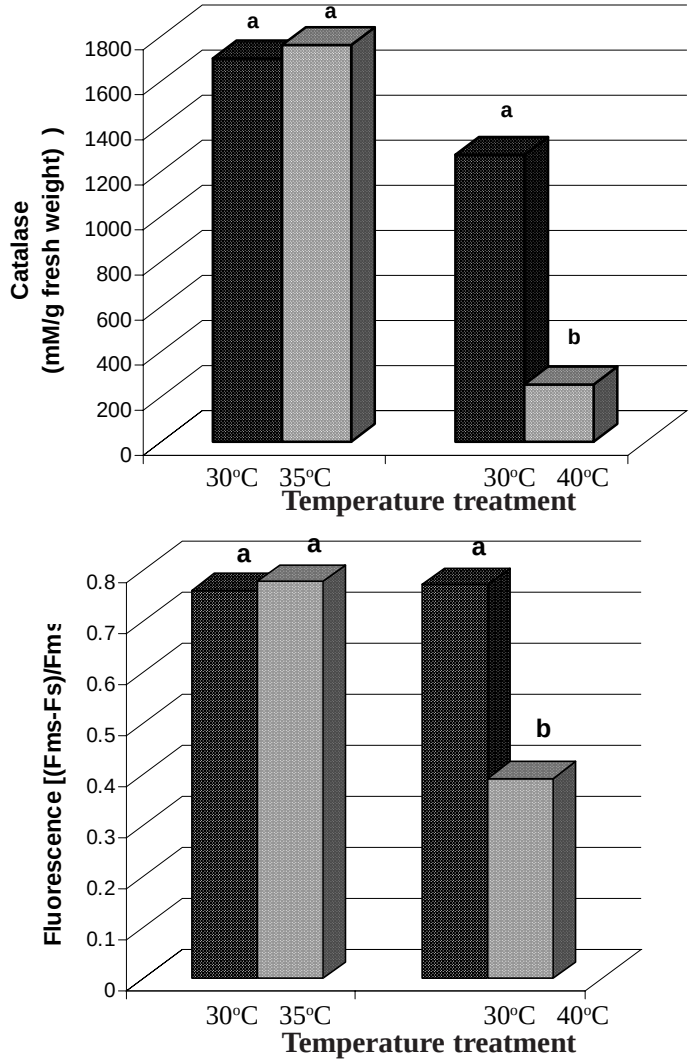


Fig. 2. Effect of elevated temperatures on proteins (A), membrane leakage (B), catalase (C), and fluorescence (D) of field- grown cotton. Fayetteville, Ark, 2003. Different letters above the paired columns show significant differences (P=0.05).

INCREASED PLANT PROTEIN, INSECT MORTALITY, AND YIELD WITH CHAPERONE™

D.M. Oosterhuis and RS. Brown[1]

RESEARCH PROBLEM

The plant growth regulator Chaperone™ has been reported to increase plant nitrogen levels, promote protein constituent transport, and increase overall yields. Field and growth- chamber studies were conducted in 2002 and 2003 to quantify 1) the effect of foliar applications of Chaperone on protein and endotoxin levels of cotton (*Gossypium hirsutum* L.) leaves and squares, and 2) the subsequent effect on bollworm mortality and yield.

BACKGROUND INFORMATION

Chaperone™ is a new protein enhancer that was registered by the Environmental Protection Agency in 2000 and the patent is pending. Chaperone is a combination of nitrophenols, namely sodium 5-nitroguaiacolate, sodium o-nitrophenolate and sodium p-nitrophenolate. Phenolics play a central role in plant metabolism, e.g., increased photosynthetic electron transport, improved membrane integrity, increased enzyme/protein production, increased lignin bio-synthesis, and increased fruit retention and growth (Robinson and Trevor, 1980).

Observances in transgenic cottons have shown that endotoxin levels have occasionally failed to be fully expressed under various conditions, including environmental factors and varietal differences, thus occasionally leading to less efficient insect control and subsequent yield losses. Cotton plants engineered to express the endotoxin protein, Cry1Ac, from *Bacillus thurengiensis* (*Bt*) have shown significant declines in efficacy against *Helicoverpa* spp. during the season, particularly from flowering onwards (Fitt et al., 1998). Thompson et al. (1976) reported that there was less total protein in the leaves of older plants as a result of a three- to five-fold reduction in protein synthesis over the season. Furthermore, Olsen and Daly (2000) concluded that not only is there less *Bt* protein in older plants, it appears that the protein is either less available or less toxic to neonates. The concentration of Cry1Ac protein, as a proportion of total protein, also declines during the season (Holt 1998). The phenolic properties of Chaperone may aid in transgenic cotton by alleviating non-expression or under-expression of CryIAc or a combination of CryIAc with Cry2Ab, the genes utilized for expression of the endotoxin protein, *B. thuringiensis*.

[1] Distinguished professor and graduate assistant, respectively, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

RESEARCH DESCRIPTION

Field and growth-chamber studies were conducted in 2001, 2002, and 2003 to quantify t 1)he effect of foliar applications of Chaperone on protein and endotoxin levels of cotton leaves and squares, and 2) the subsequent effect on bollworm mortality and yield.

Growth Chamber Study

Cotton (*Gossypium hirsutum* L.) cv. DP 33B was planted in March 2002 at the Altheimer Laboratory, University of Arkansas, into 2 L pots containing a soilless horticultural mix. The growth chamber was set for a 12-h photoperiod, with day/night temperatures of 30°F/25°C and relative humidities of 60 to 80%. Plants were arranged in a completely randomized design with three replications. All pots received half-strength Hoagland's nutrient solution daily to maintain adequate nutrients and water. Chaperone treatments were applied as a foliar spray with a CO_2 backpack sprayer calibrated to deliver 10 gallons H_2O/acre. The adjuvant, Penetrator Plus at 0.05% v/v was used. Chaperone treatments were sprayed at the seventh true leaf and the upper expanded main-stem leaf was sampled 10 days later. Treatments were sprayed again at the seventh true leaf +10 days and leaves and squares sampled 5 days later. Sampled tissues were placed in ziploc bags and immediately taken to the University of Arkansas Entomology Department for bollworm mortality testing. Bollworm mortality was assessed by placing single one-day old neonate bollworms on leaf sections in individual plastic cups with agarose in an incubator at 26°C. Mortality rates were assessed at 24, 48, 72, and 96 hours from the initiation of feeding for samples collected following the first spray application and assessed at 72 and 96 hours following the start of feeding for samples taken after the second spray application. In 2001 and 2002, main-stem leaves along with the accompanying petioles and first-position squares were sampled four main-stem nodes from the terminal at 5 and 10 days after Chaperone application, placed immediately on dry ice, and shipped to the Agdia testing facility to be analyzed for *Bt* endotoxin levels.

Field Studies

Cotton (*Gossypium hirsutum* L.) cultivar Suregrow 215*Bt*/RR was planted in early May 2002 and 2003 in a Captina silt loam at Clarkedale in northeast Arkansas, and in Fayetteville in northwest Arkansas. The design was a randomized complete block with three replications. Fertilizer, pesticides, and irrigation practices were according to current extension recommendations. Treatments consisted of an untreated control and single foliar applications of Chaperone at first flower (FF) applied at 2.5, 5, 10, and 20 oz /acre, and two applications of Chaperone at mathead square (MHS) and FF at 2.5, 5, and 10 oz/acre in 2002. In 2003, Chaperone was

applied at a rate of 5 oz/acre at MHS and FF. Yields were determined by mechanically harvesting the middle two rows of each four-row plot and components of yield and fiber quality were determined from a two-meter sample from each plot. The methods for testing for neonate mortality and the times for testing for mortality were the same as in the growth-chamber studies. Measurements were made at select times each season and included leaf and square protein concentrations analyzed at the University of Arkansas (Bradford, 1976), leaf and square endotoxin concentration (conducted by Agdia), insect mortality (University of Arkansas Department of Entomology), and yield and yield components.

RESULTS AND DISCUSSION

Effect of Chaperone on Cotton Yield

Foliar application of Chaperone in field trials at two locations in Arkansas for three years increased lint yields by an average of 61 lb/acre (Fig. 1). This yield increase was associated with increased plant protein levels (Fig. 2). Increased yields have also been reported for three years from numerous consultant field trials across the US Cotton Belt (Lackey et al., 2004).

Effect of Chaperone on Protein Content of Leaves and Squares

In 2002, in the field study at Clarkedale, foliar application of Chaperone at first flower caused an increase (47.7%) in leaf protein content (Fig. 2). Similarly, in 2003, there was a numerical but not significant ($P \leq 0.05$) increase in leaf protein from Chaperone applications in Fayetteville (+2.1%) and Clarkedale (+7.7%) compared to the untreated control.

Effect of Chaperone on Endotoxin Levels in Leaves and Squares

In the 2001 field study at Clarkedale, Chaperone caused a significant increase in endotoxin levels in leaves, petioles, and squares, particularly at the higher concentrations of Chaperone (Fig.2). Similarly, in the 2003 field study in Clarkedale there was a trend for Chaperone to increase endotoxin levels of the squares (data not shown). The increase in endotoxin was associated with the enhanced protein levels observed in growth-chamber and field studies. It has been observed that a reduction in the amount of expressed endotoxin protein occurs as plants mature leading to a loss of efficacy in the latter stages of the growing season and thus increasing the probability of surviving pests which may develop immunity to the endotoxin protein (Greenplate, 1999; Benbrook and Hansen, 1997). Chaperone appears to be a viable means for enhancing endotoxin levels and thereby improving insect mortality.

Effect of Chaperone on Bollworm Mortality on Leaves and Squares (2002-2003 Field Studies)

Increases in bollworm mortality were recorded in the growth-chamber study in Fayetteville in 2002 (Fig. 4). These results indicated that all Chaperone treatments resulted in higher bollworm mortality compared to the untreated control, and also that mortality increased with increasing rates of Chaperone. Likewise, field studies in Arkansas have confirmed increases in bollworm mortality following applications of Chaperone, particularly worms feeding on squares (data not shown).

PRACTICAL APPLICATION

Data from the growth-chamber and field studies in 2002 and 2003 show that foliar applications of Chaperone may be a viable means for enhancing lint yields in cotton through the enhancement of plant protein levels. Furthermore, in transgenic (*Bt*) cultivars the enhanced protein status contributes to improved late-season endotoxin levels, particularly in the squares, resulting in increased mortality of neonate bollworms feeding on the treated plants.

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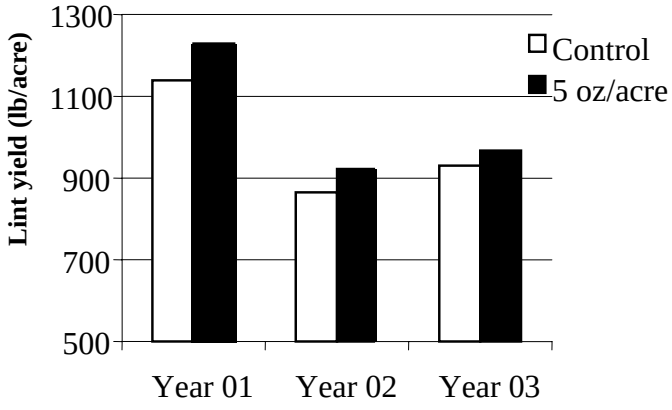

Fig. 1. Effect of Chaperone on lint yield averaged across locations in Arkansas, 2001-2003.

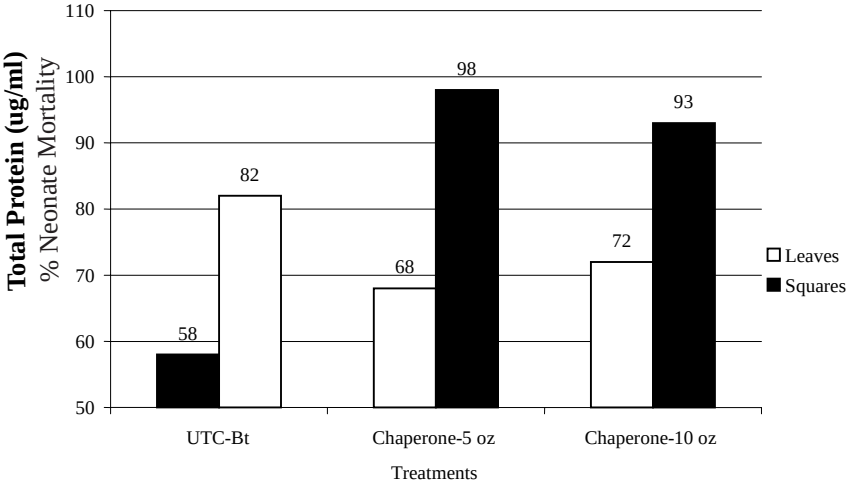

Fig. 2. Effects of Chaperone on total soluble protein in leaves at two locations in Ark., 2002-2003.

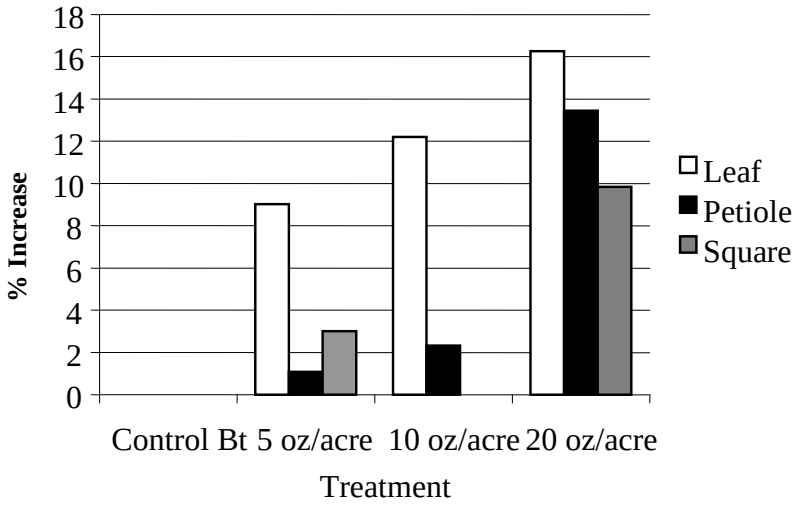

Fig. 3. Percentage increase in endotoxin level, above the control, following Chaperone applications at 5, 10 and 20 oz/acre.

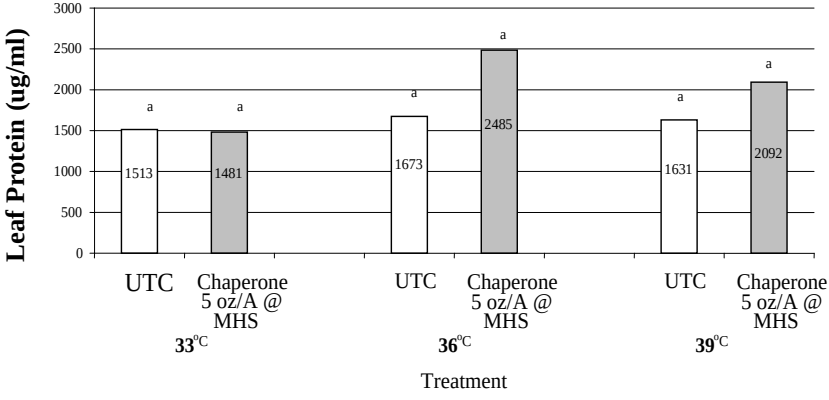

Fig. 4. Effects of Chaperone on neonate mortality in leves and squares. Field study, Clarkedale, Ark., 2002.

EFFECT OF FOLIAR CHAPERONE™ APPLICATIONS UNDER ELEVATED TEMPERATURES ON THE PROTEIN CONCENTRATIONS AND PHYSIOLOGICAL RESPONSES OF COTTON

R.S. Brown and D.M. Oosterhuis[1]

RESEARCH PROBLEM

Variability of endotoxin expression and/or concentration within transgenic cotton (*Bt*) varieties has been and continues to be a concern of cotton growers, researchers, and breeders. While not a consistent problem, it can cause major economic problems. On occasions, transgenic cotton crops require additional late-season insecticide sprays due to the probable lack of endotoxin expressed in the cotton plant. This variation in endotoxin efficiency could be due to the inactivation of the introduced gene leading to a reduction in the amount of toxin produced. It is speculated that this lack of endotoxin production may be due to increased environmental stresses such as elevated temperatures and high light intensity. Information on the impact of environmental stresses (particularly elevated temperatures) on protein and endotoxin production is needed in order to make management decisions surrounding current transgenic cotton lines and for the development of new ones. From a management perspective, applications of Chaperone during elevated temperatures might be a means of improving protein and endotoxin concentrations and thereby enhancing yields from increased mortality of bollworms.

BACKGROUND INFORMATION

Chaperone is a new *Protein Enhancer* for transgenic plants, registered by the EPA in 2000, and has a patent pending. Chaperone is a combination of nitrophenols, namely sodium 5-ntroquaiacolate, sodium 0-nitrophenolate, and sodium p-nitrophenolate. Phenolics play a central role in plant metabolism and growth and they are known to increase photosynthetic electron transport, improve/protect membrane integrity, and increase enzyme/protein production (Robinson, 1980). Observations in transgenic cottons have shown that endotoxin levels have occasionally failed to be fully expressed under various conditions, including environmental factors and varietal differences, thus occasionally leading to less efficient insect control and yield losses. Our hypothesis is that utilization of the phenolic properties of Chaperone in transgenic cotton would aid in alleviating non-expression of Cry1Ac (BOLLGARD™ by Monsanto) or a combination of

[1] Graduate assistant and distinguished professor, Crop, Soil, and Environmental Sciences Department, Fayetteville, respectively.

Cry1Ac with Cry2Ab, which are the genes currently utilized for expression of the endotoxin protein *Bacillus thuringiensis*. It has been observed that a reduction in the amount of expressed endotoxin occurs as plants mature, leading to a loss of efficacy in the latter stages of the growing season thus increasing the probability of surviving pests which may develop immunity to the endotoxin (Greenplate, 1999; Benbrook and Hansen, 1997). The objective of this growth-chamber study was to determine the efficacy of a single foliar application of Chaperone under elevated temperatures on leaf protein concentrations and physiological responses of the cotton plant.

RESEARCH DESCRIPTION

A growth-chamber study was initiated fall 2003 at the University of Arkansas, in Fayetteville, to determine the effect of a single application of Chaperone at pinhead square on leaf total soluble protein concentration and physiological responses under elevated temperatures. The study was arranged in a completely randomized design with two treatments replicated four times. The treatments included Chaperone at a 5 oz/A rate applied at pinhead square and an untreated control. The adjuvant penetrator plus at 0.05% V/V was used along with the Chaperone application. Cotton (*Gossypium hirsutum L.*) cultivar ST 4892BR was planted in 2L pots filled with sunshine mix and watered with a half-strength Hoagland's nutrient solution as needed to maintain moisture and plant nutrient levels. The growth chamber was set for a 12-hour photoperiod, with initial day/night temperatures of 30/25^{o}C and relative humidities of 60 to 80%. At pinhead square, Chaperone was applied to four plants, which along with four control plants, were moved to a second growth chamber programmed with the same day length and humidity as the first growth chamber but programmed for an elevated daytime temperature of 33^{o}C. Three days after transferring the control and Chaperone-treated plants to the second chamber programmed for elevated temperatures, measurements were made on plants from the two growth chambers (i.e with contrasting temperatures). Measurements included total soluble leaf protein, photosynthesis, chlorophyll fluorescence, and membrane integrity. Following this set of measurements, two additional sets of plants grown in the original growth chamber at 30/25^{o}C were sprayed three days apart and moved to the second growth chamber programmed for elevated temperatures of 36/25^{o}C and 39/25^{o}C. Plants were initially planted three days apart to insure that measurements at the different temperature regimes would be performed on plants of the same age. This would prevent any added doubt that the results were due to stage-dependent differences in plant development and not to treatment effects.

RESULTS AND DISCUSSION

Total Soluble Protein Concentrations

Late-season insecticide applications are often warranted due to the probable lack of expression of *Bt* endotoxin, especially under high temperatures. It was hypothesized that foliar-applications of Chaperone may be a viable means for increasing the efficacy of endotoxin and protein concentrations under elevated temperatures. Results from the growth chamber experiment in 2003 indicated that a single application of Chaperone under elevated temperatures numerically increased total leaf protein compared to the untreated control (Fig. 1). At 33°C, there was no difference between the control and Chaperone treatments for providing higher protein levels. However, under the higher temperatures (i.e. 36 and 39°C) Chaperone-treated plants had numerically higher leaf protein concentrations.

Leaf Photosynthesis

Measured leaf photosynthesis indicated no differences between the control and Chaperone-treated plants for improved leaf photosynthetic efficiency across the range of tested temperatures (Fig. 2). This result was not surprising given that leaf photosynthesis often times will not be reduced until temperatures above 40°C predominate.

Leaf Fluorescence

Leaf chlorophyll fluorescence was significantly decreased from applications of Chaperone at 33°C, 36°C or 39°C (Fig. 3). This indicates that Chaperone-treated plants were exhibiting less stress at the elevated temperature regimes, in support of the hypothesis that Chaperone applications lessen the detrimental effects of high temperatures on photosynthesis.

Leaf Membrane Integrity

Leaf membrane leakage, a measure of cell integrity, helps to explain the potential efficiency of the cotton plant for maintaining optimal cell metabolism essential for production of the developing fruit load. Results indicated that Chaperone numerically improved cell integrity (decreased leaf-membrane leakage) across all temperatures tested (Fig. 4). The positive effect of chaperone on membrane leakage was significantly compared to the untreated control at 36°C but not at 33°C or 39°C (Fig. 4).

PRACTICAL APPLICATION

Foliar-applied Chaperone under elevated temperatures appears to be a

viable means for increasing protein concentration and, therefore, the efficiency of endotoxin expression. Increased protein and endotoxin expression from Chaperone applications under environmental stress conditions is the probable reasons for the increased bollworm mortality and increased lint yields that have occurred in our field trials (Oosterhuis and Brown, 2003). In addition, improved efficiency from foliar applications of Chaperone may also improve the overall physiological functioning of the cotton plant.

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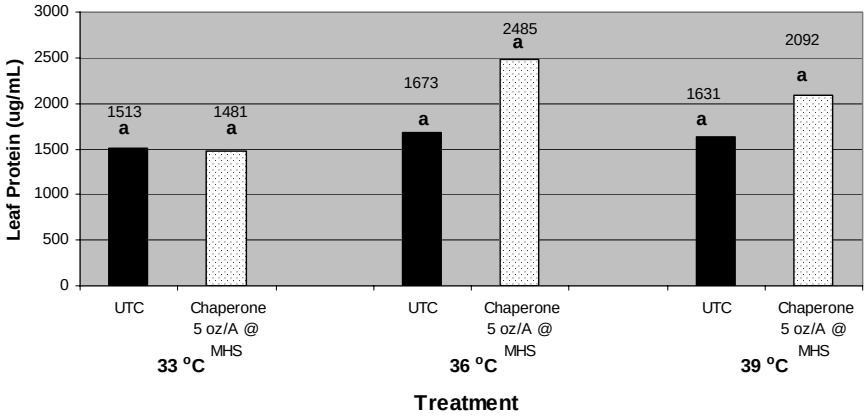

Fig. 1. Effect of Foliar Applications of Chaperone Under Elevated Temperatures on Total Leaf Protein Concentrations. Bars with the same letter are not significantly different at P ≤0.05.

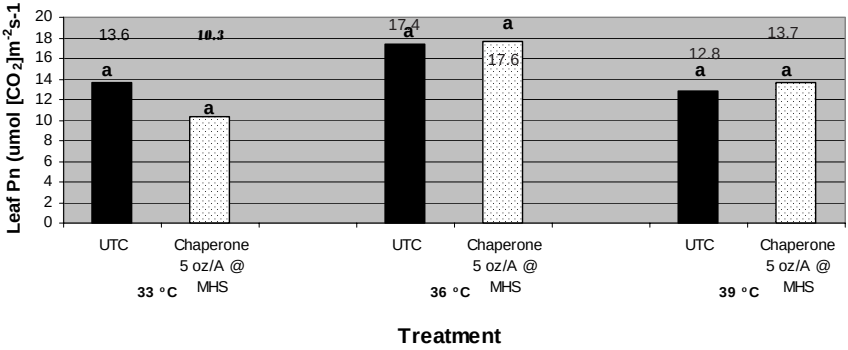

Fig. 2. Effect of Foliar Applications of Chaperone Under ElevatedTemperatures on Leaf Photosynthesis. Bars with the same letter are not significantly different at P≤0.05.

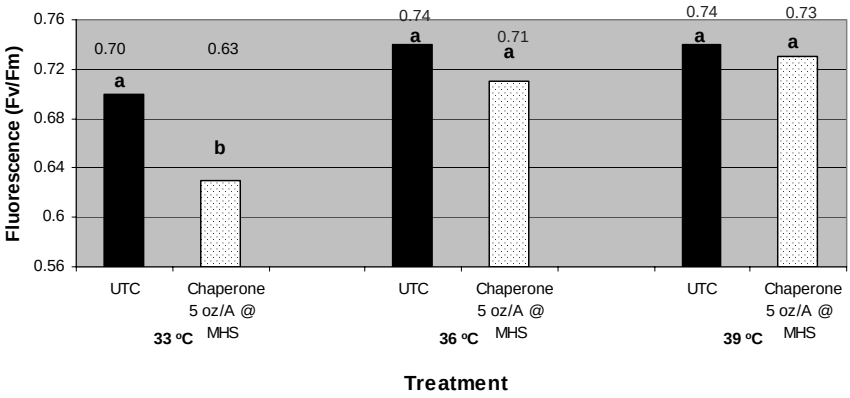

Fig. 3. Effect of Foliar Applications of Chaperone Under Elevated Temperatures on Leaf Fluorescence. Bars with the same letter are not significanlty different at P≤0.05.

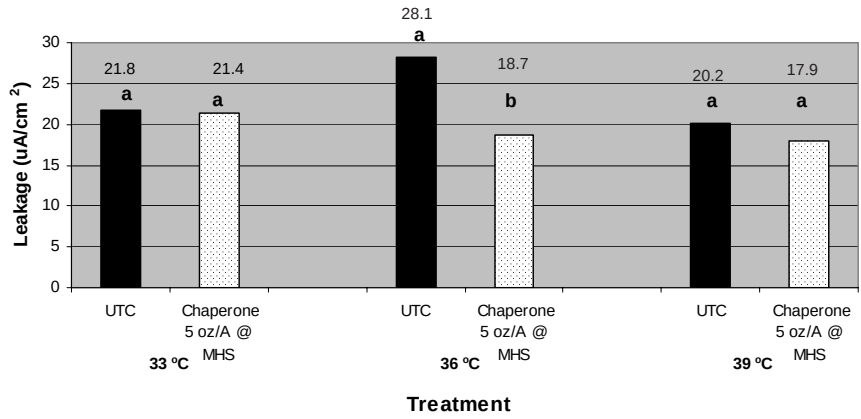

Fig. 4. Effect of Foliar Applications of Chaperone Under Elevated Temperatures on Leaf membrane Leakage. Bars with the same letter are not significanlty different at P≤0.05.

EFFECT OF TRIMAX™ INSECTICIDE APPLICATIONS UNDER WATER-DEFICIT STRESS CONDITIONS ON THE LINT YIELD AND PHYSIOLOGY OF FIELD-GROWN COTTON

D.M. Oosterhuis, R.S. Brown, and E.D. Gonias[1]

RESEARCH PROBLEM

Imidacloprid, the active ingredient in Trimax™, has proven to be an effective insecticide for controlling harmful cotton insect pests such as cotton aphids, banded winged whiteflies, plant bugs, and fleahoppers. However, the benefits of Trimax insecticide appear to extend beyond the scope of insect control. Apart from pest management, research has shown that multiple-application spray programs of Trimax, beginning early-to mid-season, have resulted in enhanced plant growth and increased yields even in situations where insect populations are low. However, information is lacking on the physiological mechanisms by which Trimax affects plant growth and thereby enhances yields.

BACKGROUND INFORMATION

Trimax insecticide is a new Imidacloprid product discovered by Bayer in 1985 and was the first commercially introduced insecticide in the class of chloronicotinyl insecticides. Trimax provides control of the major sucking/piercing insects in cotton and also has ovicidal effects on bollworms and budworms. Trimax can be applied up to five times per growing season, allowing multiple applications in sustained pressure and multiple pest situations. Imidacloprid, the active ingredient in Trimax, is the only insecticide in the nitroguanidine subclass of chloronicotinyl insecticides with a chloropyridine side chain. This distinguishing side chain is structurally related to compounds like nicotinamide and chloronicotinic acid known as systemic plant resistance-inducers. These substances have been reported to help plants better tolerate environmental stresses such as drought and excessively high temperatures.

[1] Distinguished professor, graduate assistant, and graduate assistant, respectively, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

It is hypothesized that the reported growth and yield advantage imposed by Trimax may be due, in part, to improved plant physiological functioning and the activation of antioxidant enzymes to detoxify the plant of free radicals which are always present due to the numerous environmental stresses that crops face daily. Gluthathione is one such enzyme involved in a wide range of metabolic processes (Meister and Anderson, 1983) and its content increases condsiderably under stressful conditions (Smith et al., 1990). The overall objective of these studies was to study the effect of the insecticide Trimax on the growth, physiology, biochemistry, and yield of cotton under water-stressed conditions as opposed to a well-watered environment.

RESEARCH DESCRIPTION

The effect of Trimax applications during water-deficit stress conditions was studied at two separate locations in northeast (Clarkedale) and northwest (Fayetteville) Arkansas in 2002 and 2003. The study was designed as a randomized, split-plot design with six replications at both test locations. The water-deficit conditions were imposed using an irrigation system specifically designed to impose well-watered and water-deficit conditions differentially to a randomized field plot system.

Treatments at both locations consisted of (1) an untreated control, and (2) Trimax @ 1.5 oz/acre, both subjected to well-watered and water-stressed conditions. Cotton (*Gossypium hirsutum L.*) cultivar ST 474 was planted on May 16 at Clarkedale and May 22 in Fayetteville in 2002, and on May 30 at Clarkedale and May 23 at Fayetteville in 2003. Trimax was applied with a CO_2 backpack sprayer at three weekly intervals starting at pinhead square at Clarkedale in 2002 and 2003 and at Fayetteville in 2002. In 2003, at Fayetteville, Trimax was applied at three weekly intervals starting at two weeks after first flower (FF2). Trimax treatments were applied at the onset of physiology during boll development when cotton is sensitive to environmental stresses.

Physiological measurement at Fayetteville were taken 3 days after the initial Trimax application at three weeks after first flower (FF3) during peak stress and included leaf adenosine triphosphate (ATP), leaf soluble protein, and leaf membrane leakage. At harvest, lint yield and components of yield were evaluated at both Clarkedale and Fayetteville locations. Yield component data included average boll weight, seed weight, fiber seed and gin turnout (data not shown). Node above white flower (NAWF) counts were also evaluated at Clarkedale in 2002 and 2003 in order to determine if Trimax provided earlier maturity of the cotton crop (data not shown).

RESULTS AND DISCUSSION

Lint Yields and Earliness

Trimax significantly increased lint yields in 2002 at the Fayetteville test site and numerically increased lint yields at the Clarkedale location (Fig. 1). In 2002, there were no significant differences between water treatments, therefore Trimax treatments were averaged over water. In 2003, Trimax significantly increased lint yields under both well-watered and water-deficit stress conditions at Clarkedale and under well-watered conditions at Fayetteville (Fig. 2). At Clarkedale, the increase in lint yield observed by Trimax was greater under water-deficit conditions as opposed to well-watered conditions (Fig. 2) (Brown et al., 2004). Trimax also provided a significantly earlier maturing cotton crop in 2002 as indicated by NAWF counts and percent first pick (data not shown)(Oosterhuis et al., 2003).

Leaf ATP (Energy) and Total Soluble Protein

Leaf ATP concentrations were significantly lower for Trimax-treated plants under both water levels while protein concentrations were numerically higher for Trimax-treated plants (Fig. 3). The significant decrease in leaf ATP for Trimax-treated plots could be expected since proteins have a high energy requirement, and Trimax treated plots had higher leaf protein concentrations. Also, under a mild stress the Trimax plots were more efficient at translocating carbohydrates out of the leaf, and this may have used more energy.

Leaf Membrane Leakage

Leaf membrane leakage, a measure of cell integrity, helps to explain the potential efficiency of the cotton plant for maintaining optimal metabolism essential for production of the developing fruit load. It was hypothesized that leaf membrane leakage would decrease if treated with Trimax because the plants would exhibit less stress. Results in 2003 indicated that Trimax-treated plants had significantly lower leaf membrane leakage values under water-deficit conditions, (Fig.4) indicating the improved stress tolerance of the Trimax-treated plants under the water-stress conditions.

PRACTICAL APPLICATION

Multiple spray applications of Trimax insecticide applied at 1.5 oz/A resulted in yield increases in all four field studies conducted in Arkansas in 2002 and 2003, and were statistically significant in three out of the four field trials. It appears that Trimax has the potential to improve cotton lint yields even when insect populations are low and there is a favorable environment for optimal plant growth. In addition, results from the plant physiology measurements indicated that Trimax may provide added plant health benefits when applied under sub-optimal environmental conditions. i.e. drought stress. This may be due, in part, to the unique chloronicotinic side chain present in Trimax that acts as a systemic plant resistance-inducer.

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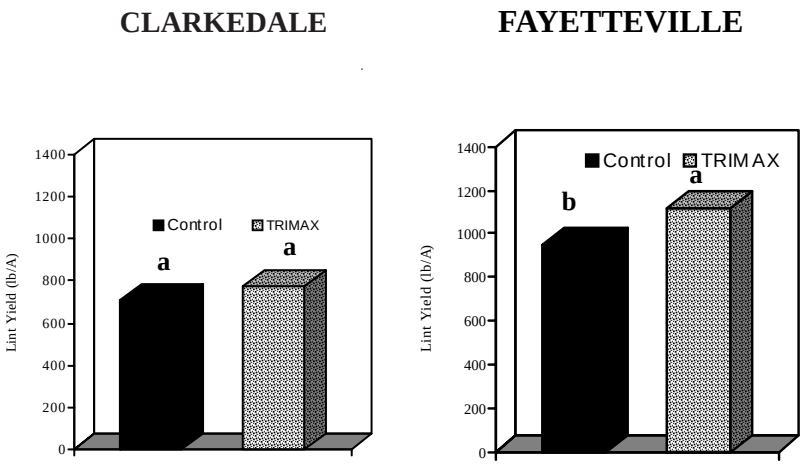

Fig. 1. Effect of foliar TRIMAX applications averaged over water treatments on lint yields at Clarkedale and Fayetteville, Ark., in 2002.

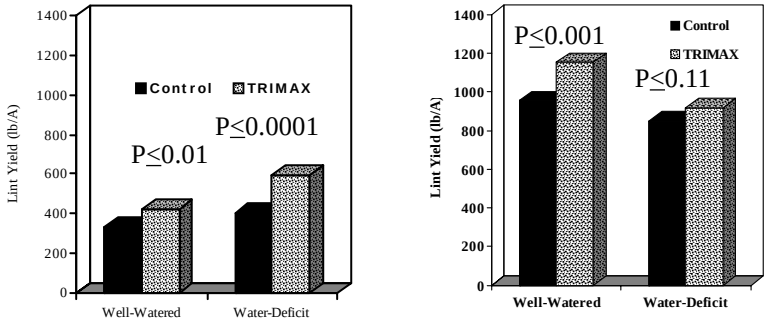

Fig. 2. Effect of foliar TRIMAX applications under well-watered and water-deficit conditions on lint yields at Clarkedale and Fayetteville, Arkansas, in 2003.

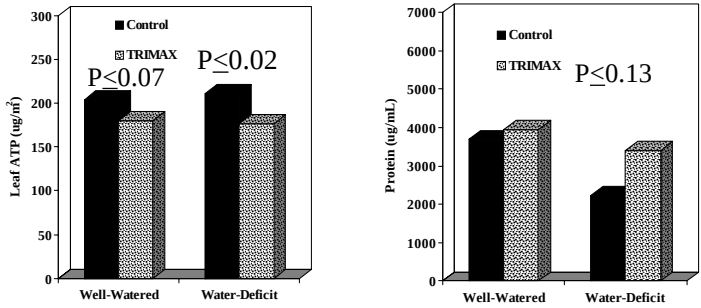

Fig. 3. Leaf ATP and leaf total soluble protein of TRIMAX-treated and untreated plots under well-watered and water-deficit conditions at Fayetteville, Ark., in 2003. Measurments made three weeks after first flower.

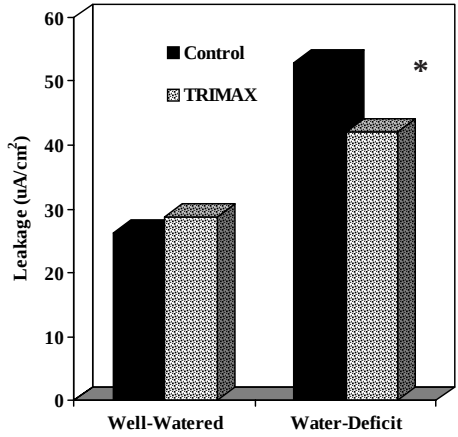

Fig.4. Leaf membrane leakage of TRIMAX-treated and untreated plots under well-watered and water-deficit conditions at Fayetteville, Ark., in 2003. Measurements made three weeks after first flower. *Indicates a significant (p<0.08) difference at the water level averaged over TRIMAX treatments.

YIELD AND PHYSIOLOGICAL RESPONSES OF MODERN VERSUS OBSOLETE CULTIVARS GROWN UNDER WATER-DEFICIT CONDITIONS

R.S. Brown, D.M. Oosterhuis, M.L. Arevalo, and A.C. Bibi [1]

RESEARCH PROBLEM

Year-to-year variability in yield is a major concern in U.S. cotton production. Recent literature and hypotheses indicate that this yield variability is mostly related to extreme environmental conditions, particularly high temperatures and drought, as well as a peak in genetic improvements in yield. It is speculated that modern and obsolete cultivars partition dry matter and energy pools differently within the boll and at the seed level, making the modern cultivars potentially more sensitive to environmental stresses. The goal of this current field study was to quantify the effect that water-deficit stress had on modern versus obsolete cultivars in terms of lint yield, components of yield, and physiological plant responses that might hinder the overall development of yield.

BACKGROUND INFORMATION

Cotton yields in Arkansas as well as in much of the U.S. increased steadily during the 1980's, but in the 1990's there has been a leveling off with a decrease in yields in the late 1990's (Meredith, 1998; Lewis and Sasser, 1999). Of more concern, however, is the extreme year-to-year variability. According to Helms (2000), there is clearly a significant problem with the lack of uniformity in current yields. In Arkansas, three out of five seasons from 1995 to 1999 were extremely disappointing with unusually low yields (Oosterhuis, 1999), with the 1998 and 1999 crop yields being the poorest in recent history. Much of this disappointment in yields was related to extreme weather conditions and not to insect pressure. Generally, each year the cotton crop appears to have good potential at mid-season, but this potential is not always achieved at harvest due to combinations of moisture stress and high temperatures during the critical first three to five weeks of boll development. Besides environmental conditions, changes in breeding objectives over the past few decades may also be an underlying reason for yield variability. It is hypothesized that increased yield variability may be the result of differential partitioning of carbohydrate and energy pools between fiber and seed of modern and obsolete cultivars as a result of environmental stress during early boll development. To test this research hypothesis the following research objectives were initiated.

[1]Graduate Assistant, distinguished professor, graduate assistant, and graduate assistant, respectively, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

The first objective was to evaluate lint yield and boll and yield components of modern versus obsolete cultivars under well-watered and water-deficit conditions. The second objective was to study physiological responses of modern and obsolete cultivars in order to better understand boll development and yield as affected by environmental stresses. An improved understanding of physiological differences between modern and obsolete cultivars under water-deficit stress should help to clarify yield development and potentially answer yield variability issues.

RESEARCH DESCRIPTION

Field studies were conducted in northeast and northwest Arkansas in 2003 to test the impact that contrasting environmental conditions coupled with genotypic differences had on partitioning in field grown cotton. The study contained two factors which were water and cultivar. Water was the whole plot factor and consisted of either well-watered or water-deficit conditions. The sub-plot factor was cultivar and consisted of eight cultivars (four modern and four obsolete). The modern cotton (*Gossypium hirstum* L.) cultivars were ST 474, SG 747, DP 33B, and Acala Maxxa and the obsolete cultivars included ST 213, DP 16, REX, and Acala SJ2. Each of these eight cultivars was subjected to both water treatments and replicated six times. Numerous in-season physiological and end-of-season agronomic measurements were evaluated to help explain yield variability. Physiological measurements included leaf fluorescence measured with a fluorometer, canopy temperature measured with a hand held infrared thermometer, chlorophyll content taken with a Minolta SPAD meter, specific leaf weight (SLW) or leaf thickness, leaf adenosine triphosate (ATP) measured with an ATP lumitran, leaf total soluble protein utilizing the Bradford method through colorimetric procedures, leaf membrane integrity measured with a conductivity meter, leaf wax concentrations and leaf antioxidant enzyme concentrations. End-of-season measurements included lint yields, yield and boll components, gin turnout, and fiber quality. Boll components consisted of average boll weight, seed weight fiber per seed, and seeds per boll. Yield components consisted of bolls per acre and seeds per acre.

RESULTS AND DISCUSSION

The 2003 season was the third year for the project investigating the yield and physiology of modern versus obsolete cultivars under water-deficit conditions. Unfortunately, the 2001 and 2002 seasons resulted in above-average rainfall during the growing season. As a result we were unable to impose moderate water-stress conditions during boll development to properly evaluate physiological differences between modern and obsolete cultivars in response to water stress as a means of explaining yield differences and arising yield variability questions. Fortunately, in 2003 we were able to obtain an appreciable water-deficit stress at the Fayetteville, Arkansas, location. This report will include some of the physiological results from the Fayetteville location in 2003, and yield and yield component results from both

the Clarkedale and Fayetteville locations collected in 2003. Results will be presented as the average of the four obsolete and the average of the four modern cultivars and presented as modern versus obsolete cultivars under each water level.

Lint Yields

In 2003, modern cultivars had higher lint yields than the obsolete cultivars at both test locations under both well-watered and water-deficit conditions (Fig. 1). At the Fayetteville test site this increase in lint yield by the modern cultivars was significant at $P \leq 0.05$. Our hypothesis was that obsolete cultivars would yield higher than modern cultivars under a significant stress event, such as water-deficit stress, due to improved partitioning of carbohydrates between fiber and seed. However, the modern cultivars yielded higher than obsolete cultivars even under water-deficit conditions. An explanation for this might be that the stress did not last long enough during boll development and compensation occurred giving the modern cultivars the advantage to yield higher since modern cultivars contain more seeds per acre, which give rise to more fiber/acre, since modern cultivars have equal or more fiber/seed (Tables 1&2) than obsolete cultivars.

Yield Components

Boll and yield component data from Clarkedale (Table 1) and Fayetteville (Table 2) showed similar results when comparing modern cultivars to the obsolete. At Clarkedale, obsolete cultivars had significantly ($P \leq 0.05$) larger bolls and greater seed weight than the modern cultivars at both water levels (Table 1). However, the modern cultivars had significantly ($P \leq 0.05$) more bolls and seeds per acre than the obsolete cultivars (Table 1). There were no significant differences between modern and obsolete cultivars for producing fiber/seed. This indicates that the improved yields by the modern cultivars (Fig. 1) were the result of more bolls and more seeds per acre with fiber per seed being near equal between modern and obsolete cultivars. There were no significant trends in relation to seeds/boll between modern and obsolete cultivars (Table 1). However, the obsolete cultivars had numerically more seeds/boll than the modern cultivars, which was not expected and difficult to explain. Boll and yield component data from the Fayetteville test site (Table 2) showed the same trend as Clarkedale with increased boll weight and seed weight with obsolete cultivars and more bolls and seeds per acre with modern cultivars. However, the only significant differences were detected under the water-deficit conditions and not under well-watered environments.

Leaf ATP Concentrations and Leaf Soluble Protein

ATP concentrations and total soluble protein levels of cotton leaves were measured to determine any differences in plant energy dynamics. There were no significant differences ($P \leq 0.05$) in measured ATP or protein concentrations at the water or cultivar level (Fig. 2). However, modern cultivars had numerically higher

ATP and protein concentrations under each water level compared to the obsolete cultivars. It was also noticed that protein concentrations were higher under well-watered conditions, but ATP concentrations were lower under well-watered conditions. An explanation for this might be that under well-watered conditions the cotton plant is better suited for making protein than are water-stressed plants; however, this manufacturing of protein cost the plant more energy (ATP).

Leaf Wax Concentrations and Leaf Membrane Integrity

There were no significant differences between modern and obsolete cultivars at either water level for altering leaf wax concentrations or leaf membrane leakage (a measure of leaf integrity). However, membrane leakage was significantly greater ($p \leq 0.05$) in water-stressed leaf samples compared to well-watered leaf samples and obsolete cultivars exhibited less leakage under water-deficit conditions (Fig. 3). Leaf membrane leakage appears to be an excellent technique for quantifying water stress. This measurement also supported our hypothesis of improved stress resistance of obsolete cultivars under stressed environments by showing a numerical decrease in membrane leakage of obsolete cultivars compared to modern cultivars. This difference was not observed under an adequate- moisture environment.

PRACTICAL APPLICATION

In recent years increasing year-to-year variability in U.S. cotton yields has become a major problem. It is speculated that this decline and lack of uniformity in cotton yields is the result of adverse environmental conditions during boll development coupled with changing germplasm lines being developed and grown commercially. Current and ongoing research is investigating the effect of drought and high temperatures on plant physiological functioning and yield development. Results are currently being analyzed across years and locations, but it appears that modern cultivars are more sensitive to adverse environmental conditions causing lower cotton yields in seasons with drought and above-normal temperatures. An investigation of physiological responses and yield development of modern versus obsolete cultivars exposed to environmental stresses could ultimately help in the establishment of counteractive management strategies before cotton yields are adversely affected.

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Table 1. Boll and yield components of modern versus obsolete cultivars under well-watered and water-deficit conditions at Clarkedale, Ark., in 2003.

Treatment	Boll weight	Bolls/acre	Seeds/acre	Fiber/seed	Seed/weight	Seeds/boll
	g/boll	#acre	#acre	mg	g/100 seed	#boll
Modern-water	4.00	79,000[x]	2,162,000[x]	57.7	9.22	27.1
Obsolete-water	4.59[x]	57,000	1,649,000	57.8	10.40[x]	28.9[x]
Modern-dryland	4.24	96,000[x]	2,721,000x	62.5	9.28	28.1
Obsolete-dryland	4.68[x]	78,000	2,235,000	61.3	10.37[x]	28.9

[x] Significant at P≤0.05 for the paired treatments.

Table 2. Boll and yield components of modern versus obsolete cultivars under well-watered and water-deficit conditions at Fayetteville, Ark., in 2003.

Treatment	Boll weight	Bolls/acre	Seeds/acre	Fiber/seed	Seed/weight	Seeds/boll
	g/boll	#acre	#acre	mg	g/100 seed	#boll
Modern-water	3.72	312,000	8,373,000	55.1	8.55	27.1
Obsolete-water	3.72	281,000	7,584,000	51.0	8.88	27.0
Modern-dryland	4.16[x]	285,000[x]	7,718,000[x]	56.0	8.57	27.0
Obsolete-dryland	3.77	235,000	6,527,000	57.0	9.46[x]	27.7

[x] Significant at P≤0.05 for the paired treatments.

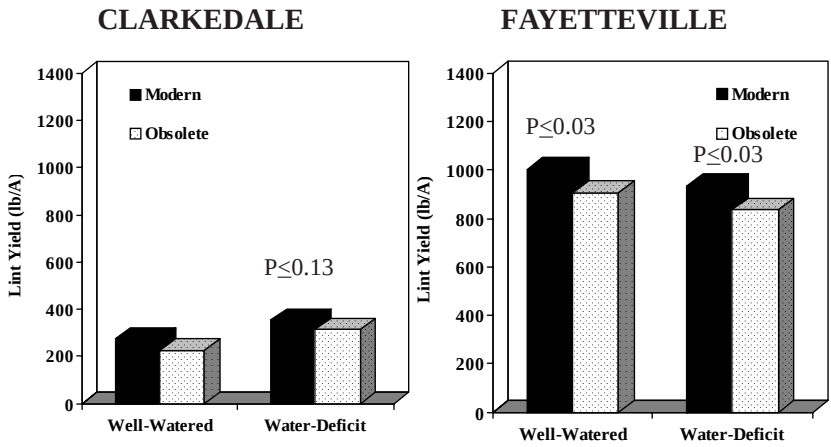

Fig. 1. Lint yields of modern versus obsolete cultivars under well-watered and water-deficit conditions at Clarkedale and Fayetteville, Ark., in 2003. The level of significance is presented above each set of columns.

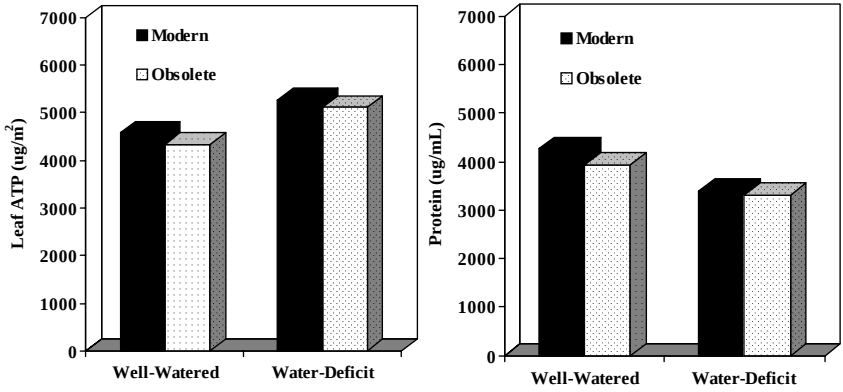

Fig. 2. Leaf ATP and leaf total soluble protein of modern versus obsolete cultivars under well-watered and water-deficit conditions at Fayetteville, Ark., in 2003. No significant differences existed between treatments at P≤0.05.

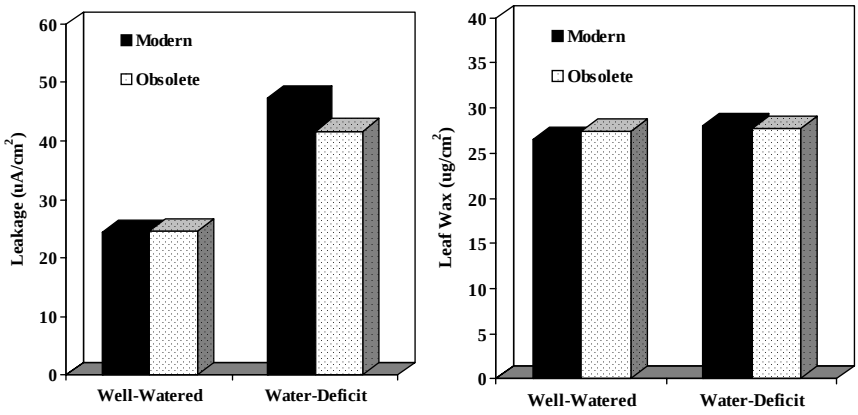

Fig. 3. Leaf membrane leakage and leaf wax concentration of modern versus obsolete cultivars under well-watered and water-deficit conditions at Fayetteville, Ark., in 2003. * Indicates a significant ($P \leq 0.05$) difference under water-deficit conditions averaged over cultivars.

EFFECT OF NIGHT TEMPERATURES ON BOLL GROWTH AND YIELD

M. Arevalo, D.M. Oosterhuis, D.L. Coker, and R.S. Brown[1]

RESEARCH PROBLEM

Explaining variability of cotton yield in Arkansas has become a major concern among farmers and researchers during the last decade. Understanding the causes of yield variability will help in the development of new management systems to counteract this problem. Two possible causes of the year-to-year variability in cotton have been identified: changes in genotype (Lewis, 2000) and environmental stresses, particularly water-deficit and high-temperature stress (Brown et al., 2003). Studies have shown a negative correlation (Fig 1) between high temperatures during boll development and yields in the mid-South (Oosterhuis, 1994). Furthermore, high temperatures during the day followed by high night temperatures may exacerbate this detrimental effect and provide an important cause of yield variability (Oosterhuis, 2002). This study was designated to investigate and quantify the effect of high night temperatures on boll growth and yield.

BACKGROUND INFORMATION

The ideal temperature range for cotton growth is between 68 to 86ºF (Reddy et al., 1991). However, temperatures in the US Cotton Belt during mid-season boll development are usually well above this optimum for growth. Cotton metabolism decreases dramatically with high day temperatures, especially fluctuations above the thermal kinetic window of 74 to 90ºF which may pose limitations on enzyme functions (Burke et al., 1988). When high day temperature conditions are followed by high night temperatures, a significant reduction in yield due to an increase in respiration can be expected. Understanding the impact of high temperatures on boll growth and yield will permit producers to make more accurate decisions about the value of additional management inputs based on heat units and predicted yield. Furthermore, if we know what is happening to the boll load, we can devise possible methods to counteract the problem, e.g., breeding for temperature tolerance or irrigating at appropriate critical times.

[1] Graduate assistant, distinguished professor, research specialist, and graduate assistant, respectively, Department of Crop, Soil, and Environmental Sciences Department, Fayetteville.

RESEARCH DESCRIPTION

A field study was established at the University of Arkansas Agricultural Experiment Station in Fayetteville in June, 2003 on a Captina silt loam (Type Fragiudult). The cotton cultivar Suregrow 215 BR (*Gossypium hirsutum* L.) was planted at a row spacing of 0.9 m. Plots were 5 x 2.7 m. Night temperature treatments consisted of: 1) normal ambient temperatures, 2) lowered temperatures, and 3) elevated temperatures. Temperature shelters were constructed from PVC pipes to support a plastic covering over the middle two rows in each plot. Elevated temperatures or lowered temperatures were achieved with factory space heaters or window air conditioners that blew hot or cool air, respectively, down the two middle rows. Temperature treatments were imposed during the third week of flowering from 8:00 PM until midnight for two weeks. The plastic covering was rolled over the top and sides of the shelters at the time of treatment imposition (sunset) and removed the following day at sunrise. White flowers were tagged (50/plot) in all plots during the first, second and third week after flowering in order to have three different stages of boll development exposed to the temperature treatments (i.e. at this time bolls were 1, 2, 3, and 4 weeks old). Temperature sensors (Watchdog Model 100, Spectrum Tech. Inc., Plainfield, Ill.) located at mid-canopy monitored and recorded the temperatures imposed. Tagged bolls were harvested at full maturity. Measurements of photosynthesis and respiration were made in the middle of the two-week period of night temperature treatments (day 8). Leaf samples were taken from the fourth node after completion of treatments for analysis of leaf area, dry matter, nutrient concentration, wax content, specific leaf weight, antioxidant enzymes, sugars, and chlorophyll content.

RESULTS AND DISCUSSION

Effect on Photosynthesis, Respiration, and Plant Biomass

Elevating or lowering the night temperatures had a significant effect ($P \leq 0.05$) on both photosynthesis and respiration after the two-week period of temperatures imposition (Table 1). Elevated temperature treatment caused night respiration to increase and thus affected the photosynthetic activity the following day. According to Warner et al. (1995), diurnal carbon metabolism in cotton plants responds to night temperatures and diurnal temperatures, and night temperatures affect the photosynthetic metabolism during the following day. These results confirmed our initial hypothesis regarding the negative effect of high night temperatures on plant physiological processes. There were no significant treatment differences on leaf area, leaf wax content, leaf dry matter, leaf nutrient concentration, specific leaf weight, leaf antioxidant enzymes and leaf sugars (data not shown). Only the chlorophyll content showed a numerical decrease in the elevated temperature treatments (Table 2).

Effect on Boll Development and Fiber Yield

Despite the significant reduction of photosynthesis, the fiber weight per seed from the tagged bolls was not significantly affected ($P \leq 0.05$) by the two-week period of altered temperatures. Identified stages of boll development (tagged bolls) showed no difference or numerical trend in response to the treatments. In accordance with our hypothesis we expected a decrease in fiber weight from the elevated night temperature, and younger stages to be the most affected by the treatments. Possibly the duration of elevated or lowered night temperature may not have been sufficient for a lasting effect due to subsequent compensation during the remainder of the boll development period. The total fiber yield (2m harvest) was also not significantly different ($P \leq 0.05$) (data not shown). However, a numerical trend for elevated temperatures showed decreases in lint percentage and weight of fiber per seed (Figs. 2 & 3), which, although not statistically significant, indicated the detrimental effect of high night temperatures on developing boll weight. Decreased percentage of fiber and fiber weight per seed would presumably be related to the shortage of carbohydrates for boll growth that was suggested by the increased respiration and reduced photosynthesis.

PRACTICAL APPLICATION

This study demonstrated the detrimental role of high night temperatures on boll growth and plant physiological processes. The two-week period of imposed night temperatures showed that elevated night temperatures (day temperatures were the same for all treatments) caused an increase in respiration, a decrease in photosynthesis the following day, and a numerical decrease in fiber per seed. Similarly, a lowered night temperature caused a decrease in respiration, an increase in photosynthetic activity, and an increase in fiber per seed. Yield was not significantly affected by this two-week period of elevated or lowered night temperatures due presumably to subsequent compensation during the remainder of the boll development period. Presumably, a period of extreme temperature longer than two weeks is needed for a significant effect on yield. These results help to further explain the causes of yield variability due to elevated night temperatures.

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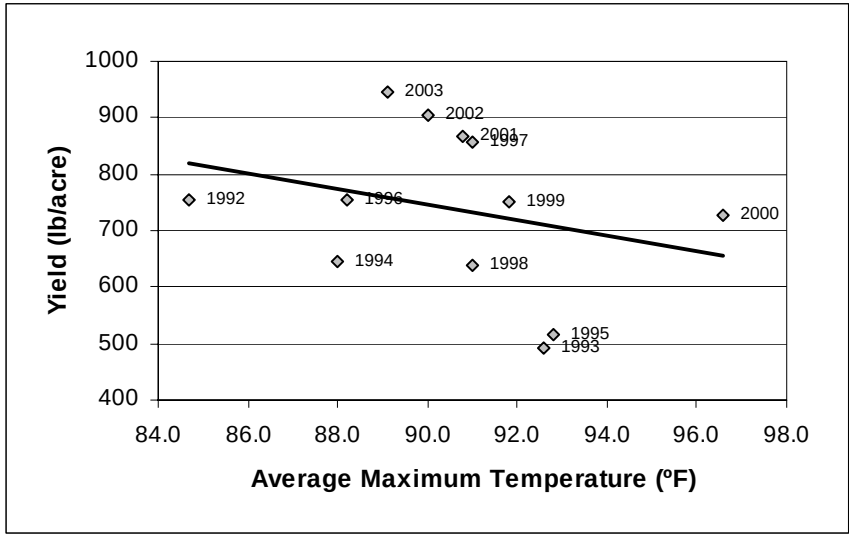

Fig 1. Correlation between yield and average maximum temperature in August. Marianna, Ark., 1992-2003.

Table 1. Photosynthesis and respiration during the two-week period of temperature treatments.

Treatments[1]	Respiration[2]	Photosynthesis[2]
	——— μmolCO²/m²/s ———	
Control (ambient)	-3.01 b[3]	24.77 b
Lowered temperature	-1.92 a	27.13 a
Elevated temperature	-3.65 b	21.04 c

[1]Night temperatures

[2]Measured eight days after initiation of temperature treatment

[3]Numbers followed by the same letter within a column are not significantly different ($P < 0.05$)

Table 2. Biomass analysis after the two-week period of temperature treatments

Treatments[1]	Chlorophyll content (after completion of treatment)	
	One day	Seven days
	--------mg/g--------	
Control (ambient)	2.68a[2]	3.13a
Lowered temperature	2.84a	2.99a
Elevated temperature	2.48a	3.01a

[1]Night temperatures
[2]Numbers followed by the same letter within a column are not significantly different (P≤0.05)

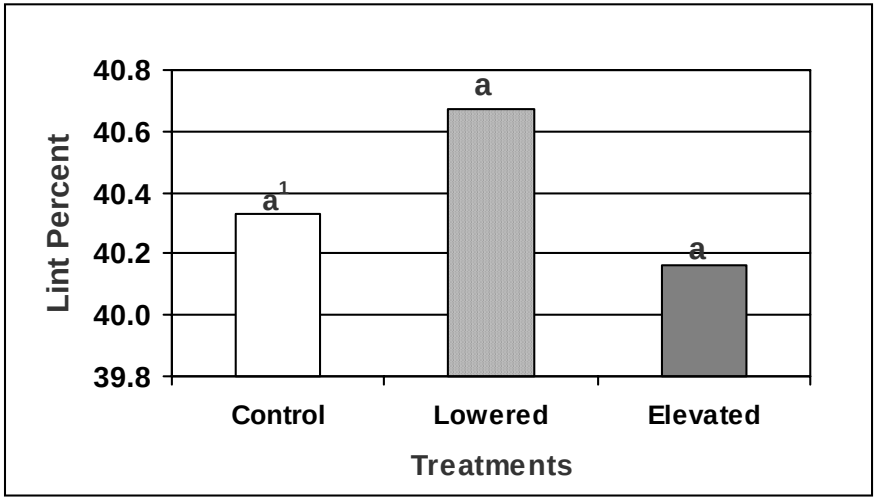

Fig. 2. Effect of night temperature on lint percent at harvest. Marianna, Ark., in 2003.
[1]Columns with the same letter are not significantly different (P≤0.05)

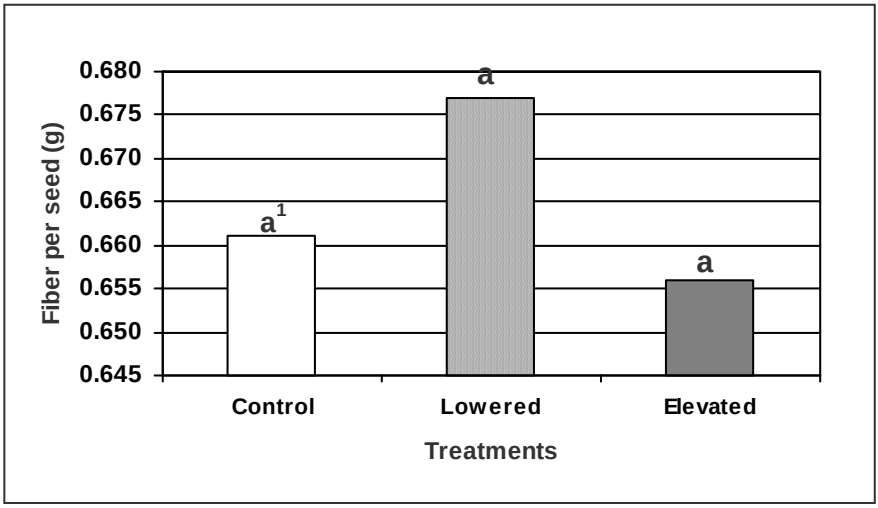

Fig .3. Effect of night temperatures on fiber weight per seed. Marianna, Ark., in 2003.

[1]Columns with the same letter are not significantly different (P≤0.05)

COTTON PLANT RESPONSE TO TRIMAX™ INSECTICIDE AND INCREASING TEMPERATURE

E.D. Gonias, D.M. Oosterhuis, A.C. Bibi, and R.S. Brown[1]

RESEARCH PROBLEM

The insecticide Trimax™ is registered specifically for use in cotton for control of the major sucking/piercing insects. In addition, Trimax also appears to provide lint yield and plant growth-enhancing properties, especially under conditions of environmental stress. This study was designed to provide information on physiological and biochemical changes occurring in cotton plants grown under increasing day temperature after foliar applications of Trimax.

BACKGROUND INFORMATION

Trimax is a new insecticide from Bayer CropScience, discovered in 1985 and registered for use on cotton (Anon., 2002). It was the first commercially introduced insecticide in the class of chloronicotinyl insecticides. Trimax provides control of the major sucking/piercing insects in cotton such as aphids, cotton fleahopper, banded winged whitefly, plant bugs (excluding *Lygus Hesperus*), green stinkbug, and southern stinkbug. It also has ovicidal effects on bollworm and budworm. The active ingredient in Trimax is Imidacloprid, the only insecticide in the nitroguanidine subclass of chloronicotinyl insecticides with a chloropyridine side chain. This distinguishing side chain is structurally related to compounds like nicotinamide and chloronicotinic acid known as systemic plant resistance-inducers. These substances help plants to better tolerate environmental stress during drought, disease, and insect attacks. It is hypothesized that the apparent growth advantage imposed by Trimax is due to physiological and biochemical changes in the plant that lessens the effect of environmental stresses. One of these changes is the activation of antioxidant enzymes that detoxify the plant of free radicals (Gould, 2003), which are always present due to the numerous environmental stresses that crops face daily.

[1] Graduate assistant, distinguished professor, graduate assistant, and graduate assistant, respectively, Department of Crop, Soil, and Environmental Sciences Department, Fayetteville.

RESEARCH DESCRIPTION

The effect of increasing day temperature on the growth response of cotton to Trimax was evaluated using two growth chambers. A randomized complete block design with four replications was used. This study was conducted in the Altheimer Laboratory growth rooms, Fayetteville, Arkansas, in October 2003. The first chamber was programmed for a 12-hour photoperiod, with day/night temperature of 20/30°C and relative humidity of 75%. The cotton (*Gossypium hirsutum* L.) cultivar Stoneville 474 was planted in 2-L pots filled with Sunshine potting media. The second growth chamber was used to expose the plants to increased day temperatures of 33, 36, and 39°C. Treatments consisted of an untreated control and Trimax at 1.5 oz./acre, split for day temperature. Trimax was applied at pinhead square with the use of a spray chamber. The third day after transferring the plants to higher day temperature, researchers measured photosynthesis, chlorophyll fluorescence, membrane integrity, chlorophyll content (SPAD measurements) and specific leaf weight. Also leaf samples were collected to determine the activity of antioxidant enzymes.

RESULTS AND DISCUSSION

No significant differences were observed in leaf photosynthesis after Trimax applications across all the temperature ranges (data not presented). However, there was a significant decrease in leaf fluorescence for Trimax-treated plants at 36°C, but no significant effect at 30°C, 33°C, or 39°C (Fig. 1.). Leaf membrane integrity was also significantly decreased from Trimax applications at 36°C, but was not significant at 30°C, 33°C, or 39°C (Fig. 2). Trimax appeared to lessen the detrimental effects of high temperature (i.e. 35°C) on chlorophyll fluorescence and cell membrane integrity. However, at higher extreme temperatures (i.e. 38°C) the beneficial effect of Trimax was greatly diminished.

Trimax also provided no significant differences across temperatures for altering chlorophyll content or specific leaf weight (data not presented). Trimax applications appeared to alter the activity of antioxidant enzymes at temperatures ranging from 30-33°C, but had no effect above 36°C (Fig. 3). Glutathione activity in particular was increased by Trimax. The activity of this enzyme has been implicated in stress tolerance (Anderson et al., 1992).

PRACTICAL APPLICATION

Trimax appears to lessen the detrimental effect of high temperature on cotton growth by maintaining the stability of the membranes and the efficiency of light absorbance for photosynthesis. Although at extreme high temperatures the beneficial effect of Trimax is dimished. These findings may help to explain the

reported growth enhancement of Trimax-treated plants particularly under conditions of environmental stress.

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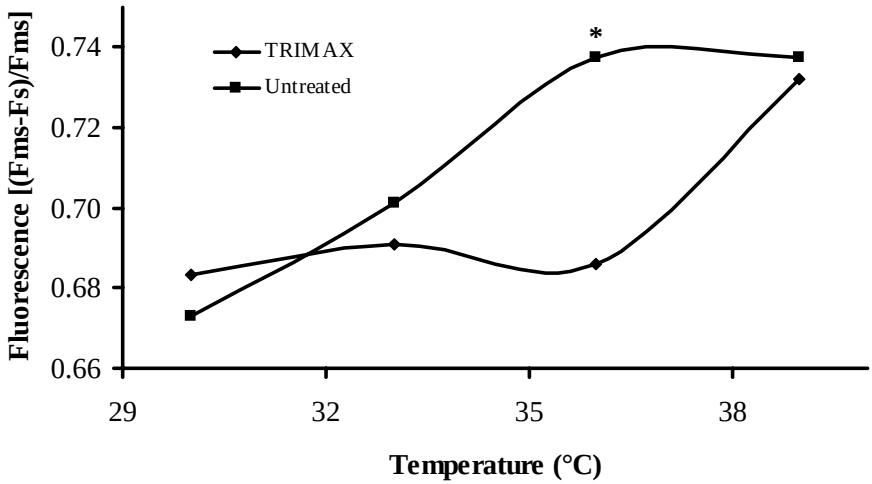

Fig. 1. Effect of Trimax on chlorophyll fluorescence with increasing temperature.

*** indicates significant differences (P=0.05) between treatments for that temperature.**

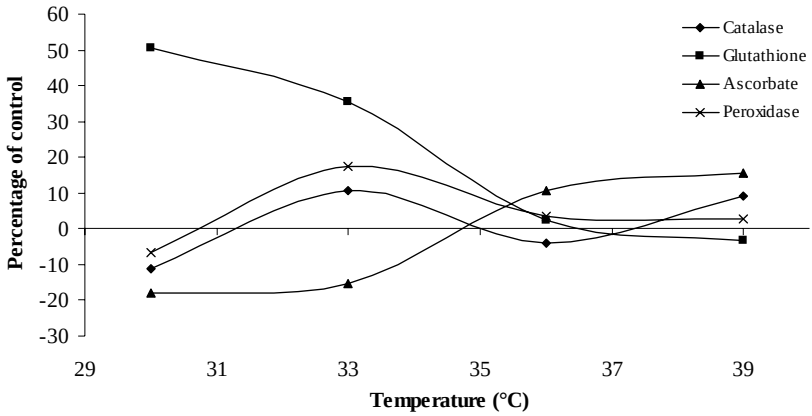

Fig. 2. Effect of Trimax on membrane integrity with increasing temperature. *indicates significant differences (P=0.05) between treatments for that temperature.

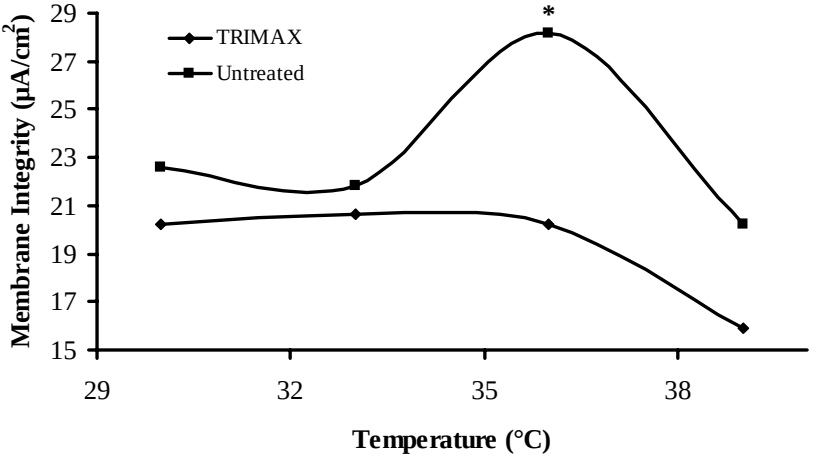

Fig. 3. Effect of Trimax on antioxidant enzyme activity with increasing temperature.

YIELD, GROWTH AND PHYSIOLOGY OF TRIMAXT™ TREATED COTTON

E.D. Gonias, D.M. Oosterhuis, A.C. Bibi, and R.S. Brown.[1]

RESEARCH PROBLEM

The active ingredient of Trimax™ insecticide is Imidacloprid. This insecticide provides control of the major sucking/piercing insects of cotton. In addition, there have been anecdotal reports of yield and growth enhancement in cotton after multiple foliar applications of Trimax. However, the information on the mode of action of the growth-and-yield enhancement properties imposed by Trimax is limited. This study was designed to understand the cotton plant response after foliar applications of Trimax.

BACKGROUND INFORMATION

Trimax is a new insecticide from Bayer Crop Science registered specifically for use on cotton. It was discovered in 1985 and was the first commercially introduced insecticide in the class of chloronicotinyl insecticides. Trimax provides control of the major sucking/piercing insects in cotton, and also has ovicidal effects on bollworm and budworm. The active ingredient in Trimax is Imidacloprid, the only insecticide in the nitroguanidine subclass of chloronicotinyl insecticides with a chloropyridine side chain. This distinguishing side chain is structurally related to compounds like nicotinamde and chloronicotinic acid, known as systemic plant resistance inducers, which are reported to help plants to better tolerate environmental stress including drought and high temperature. It is hypothesized that these properties may explain the reported growth and yield enhancement of Trimax-treated plants.

RESEARCH DESCRIPTION

Field studies were conducted in Clarkedale, northeast Arkansas, and also in Fayetteville, northwest Arkansas. Cotton (*Gossypium hirsutum* L.) cultivar Stoneville 474 was used for both studies. Trimax was applied with a CO_2 backpack sprayer starting at pinhead square.

The 2003 study at Fayetteville was planted on May 21, 2003, in a randomized complete block (RCB) design with six replications. Treatments consisted of an untreated control, Trimax at 1.5 oz/ac applied once at pinhead square, and Trimax at 1.5 oz./acre applied three times at weekly intervals starting at pinhead square.

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[1] Graduate assistant, distinguished professor, graduate assistant, and graduate assistant, respectively, Department of Crop, Soil, and Environmental Sciences Department, Fayetteville.

The study at Clarkedale was planted on May 13, 2003, in an RCB design with eight replications. Treatments consisted of an untreated control, Trimax at 0.5, 1.0, 1.5, 2.0 oz/ac applied once at pinhead square, Trimax at 0.5, 1.0, 1.5, 2.0 oz./acre applied three times at weekly intervals starting at pinhead square, and Trimax at 8 oz/100 lb seed (seed treatment).

The measurements taken included classical growth analysis (biomass and leaf area), leaf photosynthesis, specific leaf weight (SLW), chlorophyll fluorescence, membrane integrity, non-structural carbohydrate concentrations of leaves, lint yield, and the activity of antioxidant enzymes (catalase, ascorbate peroxidase, peroxidase, and glutathione reductase). For the classical growth analysis, 1-m lengths of row were sampled from each plot three weeks after first flower. Physiological measurements were made one week after each Trimax application. Photosynthesis was measured with a portable LI-6200 photosynthesis system (Li-Cor Inc, Lincoln, Neb.). Membrane leakage was measured with an automatic seed analyzer (Applied Intelligent Systems Inc. Ann Arbor, Mich.) and chlorophyll fluorescence was measured with an OS1-FL modulated chlorophyll fluorometer (Opti-Science, Tyngsboro, Mass.). Carbohydrates and sugar alcohols were measured using HPLC. The extraction procedure from leaf tissue, to determine antioxidant enzymes, was described by Anderson et al. (1992) and a BioSpec-1601 enzyme analyzer (Shimadzu Inc., Columbia, Ma.) was used for the analysis. At final harvest, lint yield was determined by mechanical harvest at Clarkedale and from 2-m hand-sampling at Fayetteville.

RESULTS AND DISCUSSION

Effect of Trimax on Lint Yield

Multiple foliar applications of Trimax during squaring had no significant (P=0.05) effect on the yield at both locations. However, in Fayetteville a numerical increase of 16 >% (+23> kg/ha) was observed after three applications of Trimax at 1.5 oz/ac. Similarly, in Clarkedale three applications of Trimax at 1.5 oz/ac showed a numerical increase in yield of 12.6% (134 kg/ha) compared to the untreated control (data not presented). This increase was similar with the increase observed after one application of Trimax at 2.0 oz./acre (12> %, 134> kg/ha). An increase of 19.3 % (195 kg/ha) was observed after three applications of Trimax at 2.0 oz/ac. These numerical increases could be attributed to small, non-significant increases in the number of bolls per meter row, average boll size, gin turnout, and amount of fiber to seed (Table 1).

Effect of Trimax on Plant Growth

Trimax applications at both locations had no significant effect on plant growth measurements (dry weight, number of nodes, plant height, leaf area and number of fruits) and on dry-matter partitioning (data not presented). The lack of

effect of Trimax on plant growth was presumably due to the mild environmental conditions experienced during the reproductive period in both locations of the study in 2003.

Effect of Trimax on Plant Physiology

The effect of Trimax on the physiology of the cotton plants was evaluated at Fayetteville, one week after each application of Trimax. The data collected one week after the third application of Trimax are presented in (Table 2). Except for photosynthesis, no statistically significant differences were observed for the physiological measurements recorded.

Effect of Trimax on Antioxidant Enzymes, Carbohydrates, and Polyols

To evaluate our hypothesis that the growth advantage imposed by Trimax is in part due to the activation of antioxidant enzymes to detoxify the plant of free radicals (Gould, 2003), the effect of Trimax application on the activity of these enzymes was evaluated with time after application (Fig. 1). Trimax caused an immediate increase in glutathione reductase and a decrease in ascorbate peroxidase. However, all enzyme activity tended towards the control value two days after Trimax application.

Three applications of Trimax caused a significant increase in the content of carbohydrates (fructose, glucose, sucrose) in leaves, and a significant increase in myo-inositol (sugar alcohol), as shown in (Fig. 2). However, a single application of Trimax at pinhead square had no significant effect on carbohydrates and polyols. Sugar alcohols (polyols) stabilize the native conformation of proteins, counteracting the detrimental effects of desiccation, and temperature extremes. Polyols are thus a mechanism that improves a plant's ability to withstand stresses. The increased activity of antioxidant enzymes and increased levels of the polyol and myo-inositol in Trimax-treated plants supports our hypothesis that Trimax helps to lessen the detrimental effect of environmental stress.

PRACTICAL APPLICATION

Although Trimax-treated cotton plants did not show significant differences in the physiological parameters measured (photosynthesis, chlorophyll fluorescence, membrane leakage) compared to the untreated plants, a numerical increase in lint yield was observed after multiple foliar applications of Trimax in both locations of the study. This yield increase can be attributed to nonsignificant enhancement of all the components of yield.

The increased activity of antioxidant enzymes and increased level of myo-inositol suggests that Trimax improves the ability of plants to withstand stress (e.g. high temperature and water deficit). Additional research is planned to help form a clearer explanation of the mechanism of the yield enhancement by Trimax.

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Table 1. Effect of TRIMAX on the yield and yield components of cotton. Fayetteville, Ark., in 2003.

Treatment	Bolls/m	Average boll size	Gin turnout	Fiber/seed	Lint yield
		[g]	[%]	[mg/mg]	[kg/ha]
Control	97.8a[1]	3.48a	40.6a	0.683a	1394.94a
Trimax x1[2]	91.7a	3.61a	41.4a	0.708a	1374.9a
Trimax x 3[2]	101.3a	3.82a	42.0a	0.727a	1631.5a
$LSD_{0.05}$	16.1	0.62	1.6	0.046	395.2

[1] Numbers followed by the same letter are not significantly different (P=0.05).
[2] Trimax at 1.5oz/acre applied once at pinhead square.
[3] Trimax at 1.5oz/acre applied three times at weekly intervals starting at pinhead square.

Table 2. Effect of Trimax on the physiology of cotton measured two weeks after pinhead square. Fayetteville, Ark., in 2003.

Treatment	Chlorophyll fluorescence	Membrane leakage	Photosynthesis	SLW1
	[(Fms-Fs)/Fms]	[μ A/cm^2]	[μmol [Co_2]/m^2/sec]	[g/m^2]
Control	0.571a[2]	22.22a	29.95 ab	65.02a
Trimax x 1[3]	0.574 a	18.78 a	28.47 b	65.69a
Trimax x 3[4]	0.558 a	23.54 a	31.84 a	67.08 a
$LSD_{0.05}$	0.035	4.62	3.29	2.34

[1] Specific Leaf Weight (Leaf Dry Weight/ Leaf Area).
[2] Numbers followed by the same letter are not significantly different (P=0.05).
[3] Trimax at 1.5 oz/acre applied once at pinhead square.
[4] Trimax at 1.5 oz/acre applied three times at weekly intervals starting at pinhead square.

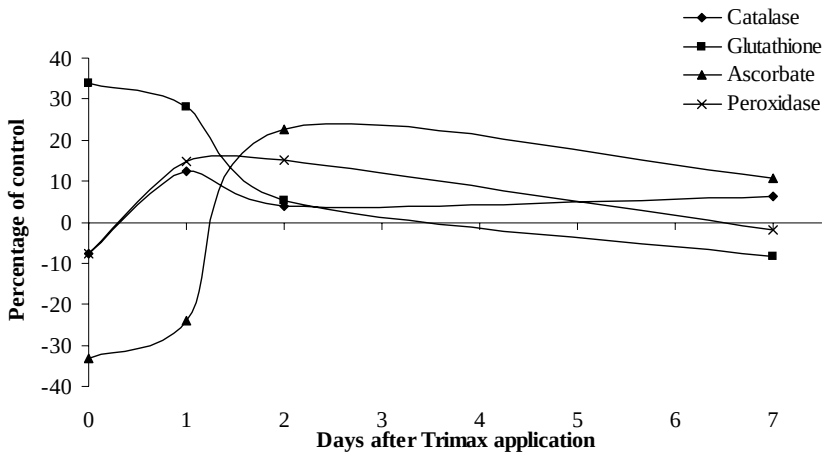

Fig. 1. Effect of Trimax on antioxidant enzyme activity for 7 days after application. Measurements started three hours after application.

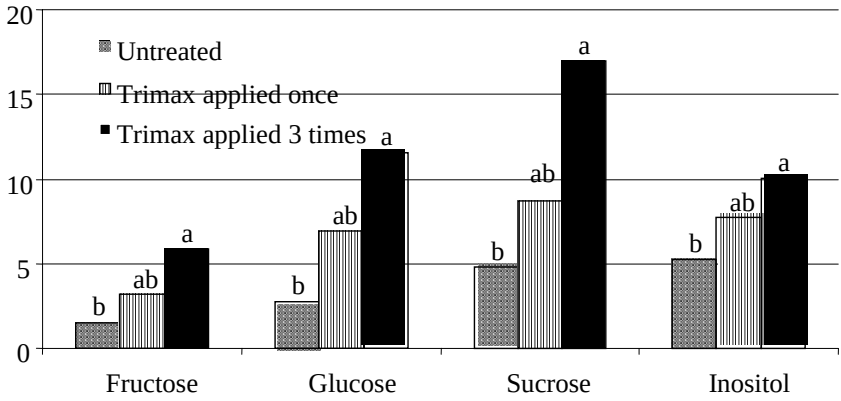

Fig. 2. Carbohydrate content in leaves measured three weeks after pinhead square. Columns superseded by a different letter are significantly different (P<0.05) Fayetteville.

COTTON GROWTH AND DEVELOPMENT AFTER APPLICATION OF ENVOKE (TRIFLOXYSULFURON) IN COTTON

J.L. Barrentine, O.C. Sparks, and M.R. McClelland[1]

RESEARCH PROBLEM

Cotton injury has been a concern in Arkansas with the herbicide Envoke™ (trifloxysulfuron or CGA-362622). In 40 Arkansas field experiments, injury from Envoke ranged from 0 to as much as 70 %. Although visual injury is usually transient and yields have not been reduced (Porterfield et al., 2002 and 2003), Arkansas weed scientists are attempting to characterize injury and define conditions under which injury from Envoke can occur. As has been evident with glyphosate, visual injury and effects on cotton development are not always correlated (Barrentine et al., 2001). Characterization of effects of Envoke on cotton growth and development is important to determine whether the injury we have observed may be affecting growth and development parameters. The objective of this study was to evaluate effects of Envoke on visual cotton response and on growth and development using COTMAN, the decision-aid program (Danforth and O'Leary, 1998).

BACKGROUND INFORMATION

Envoke is a sulfonylurea herbicide developed for post-emergence over-the-top or post-directed applications in conventional or transgenic (Roundup Ready® or BXN™) cotton. It is also formulated with prometryn as the premixture Suprend™ for post-directed application. Envoke controls several economically important weeds in cotton, including morningglory (*Ipomoea*) species, non-ALS-resistant pigweed (*Amaranthus*) species, hemp *sesbania* (*Sesbania exaltata)*, sicklepod *(Senna obtusifolia),* and purple and yellow nutsedge (*Cyperus* species) at very low use rates ranging from 0.1 to 0.25 oz/acre (Branson et al., 2002; Porterfield et al., 2003; Wells, 2000). It has soil-residual activity that can be an advantage in transgenic cotton programs. Envoke also has pre-emergence activity, but injury has been a concern (up to 49% injury) (Branson et al., 2002), and it is not labeled for pre-emergence use in cotton. Injury is usually manifested as chlorosis and stunting, but conditions under which injury occurs have not been defined.

[1] Professor and head, graduate assistant, and senior research assistant, respectively, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

RESEARCH DESCRIPTION

An experiment was conducted in 2003 at Marianna, Arkansas, on a silt loam soil. The experimental design was a randomized complete block with four replications and 13- by 40-ft plots. Paymaster 1218BR cotton was planted June 3. Plots were maintained weed-free and were furrow-irrigated as needed. Treatments included Sequence (glyphosate plus metolachlor) applied over-the-top (OT) to 2- to 3-leaf cotton followed by (fb) Envoke OT at 0.004 and 0.007 lb ai/A to 8-leaf cotton fb Suprend (prometryn plus trifloxysulfuron) at 1 lb ai/A post-directed (DIR) to 12-leaf cotton; Sequence (2- to 3-leaf cotton) fb Envoke at 0.004 lb/A (8-leaf) fb 0.007 lb/A (12-leaf); Roundup WeatherMax (glyphosate), 0.75 lb ae/A OT to 2- to 3-leaf cotton fb Roundup WeatherMax 0.75 lb/A DIR (8-leaf) fb Caparol (prometryn) plus MSMA or Valor (flumioxazin) plus MSMA (12-leaf); and Staple (pyrithiobac) at 0.031 lb ai/A plus Roundup WeatherMax (2- to 3-leaf) fb Valor plus MSMA (12-leaf). Herbicides were applied in 20 GPA output volume. Treatments at 2- to 3-leaf cotton were applied June 16, 8-leaf treatments were applied July 7, and 12-leaf treatments were applied July 22. Data collected included visual cotton injury ratings, COTMAN data, end-of-season mapping, and cotton yield. Data were analyzed by analysis of variance, and means were separated with LSD at P=0.05.

RESULTS AND DISCUSSION

Envoke caused moderate cotton injury (24 to 30%), primarily in the form of stunting, after the 8-leaf application, compared to untreated and glyphosate-treated cotton. Plants were still stunted (9 to 14%) when post-directed treatments were applied. Seedcotton yield, however, was not reduced.

The number of squaring sympodia at first flower (8.3 to 8.8) and the number of sympodia with retained first-position squares at first flower (6.8 to 7.2) were not affected by herbicide treatment. Cotton plants treated with Envoke were significantly shorter at first flower than cotton treated with Roundup WeatherMax or Staple plus Roundup WeatherMax (average of 27.2 for Envoke treatments and 30.4 inches for other treatments). Envoke also caused small reductions in height-to-node ratios (HNR), indicating that internode growth was impacted by the herbicide. The HNR parameter determined by COTMAN correlated to visual injury observed in the field. Although growth and fruiting patterns were not impacted by Envoke treatments (Fig. 1.), Envoke followed by Envoke or Envoke plus Caparol caused a 2- to 4-day delay in maturity compared to untreated cotton. End-of-season mapping indicated that herbicide treatment did not affect percent retention of first- or second-position bolls on nodes one through ten, number of outer bolls, number of sympodial branches, or final plant height.

PRACTICAL APPLICATION

Although cotton injury can appear significant after over-the-top post-emergence application of Envoke, cotton growth and development may not be affected enough to reduce cotton yield. The only parameter measured by COTMAN that reflected the visual injury attributed to Envoke was HNR. COTMAN is a valuable tool for measuring the effects of herbicides on cotton fruiting patterns and for comparing effects among herbicide treatments. However, it cannot substitute for visual injury assessments, which are of realistic concern to cotton producers.

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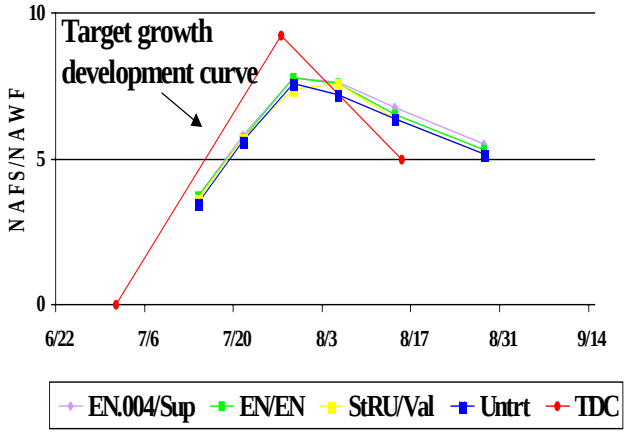

Fig. 1. Growth patterns for cotton treated with Envoke fb Suprend (EN.004/Sup) or Envoke (EN/EN), Staple + Roundup fb Valor + MSMA (StRU/Val), untreated (Untrt), and target growth-development curve (TDC) at Marianna, Ark., in 2003.

UPDATE ON GLYPHOSATE-RESISTANT HORSEWEED IN ARKANSAS COTTON

M.R. McClelland, R.E. Talbert, K.L. Smith, J.L. Barrentine, S. Matthews, and O.C. Sparks[1]

RESEARCH PROBLEM

Suspected glyphosate-resistant horseweed (*Conyza canadensis*), also called marestail, was reported in northeast Arkansas in the early months of 2003. Some plants had survived as many as three applications of glyphosate (Roundup and other glyphosate products). The movement of the resistant biotype was very rapid in Tennessee, and we suspect that will also be the case in Arkansas.

Currently, horseweed is controlled by tillage in conventional cotton production and with preplant burndown herbicides (usually glyphosate) in reduced-tillage systems. Glyphosate used as a burndown also controls other winter weeds at a cost of approximately $15 per acre ($15 × 600,000 acres that receive a burndown = $9 million in Arkansas). Control of glyphosate-resistant horseweed will increase the herbicide cost of burndown application significantly. If economical alternatives for management of the resistant biotype are not quickly formulated, many farmers may move away from conservation-tillage practices, which will increase labor and machinery costs as well as jeopardize soil conservation efforts.

Confirmation of suspected resistant populations benefits producers by allowing them to establish a management program that will control the resistant species and allows producers in the area to begin resistance-management programs before they have severe infestations. Conservation tillage is now used in more than 50% of the cotton acreage in Arkansas, so preplant herbicidal control of horseweed is important. 2,4-D and dicamba are effective options for herbicide-resistant horseweed, but they cannot be used within three weeks of planting and provide no significant residual control. More options are needed for preplant control of resistant horseweed in cotton.

BACKGROUND INFORMATION

Glyphosate-resistant horseweed was confirmed in Delaware in 2000 (VanGessel, 2001). The population was identified after a glyphosate-only program

[1] Senior research associate, professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; extension weed scientist, Southeast Research and Extension Center, Monticello; professor and department head, Crop, Soil, and Environmental Sciences Department, Fayetteville; county extension agent, Arkansas Cooperative Extension Service, Blytheville; and graduate assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville, respectively.

was used in soybean for three years, and plants exhibited an 8- to 13-fold glyphosate resistance compared to susceptible plants, which, historically, had essentially been completely controlled by glyphosate. In 2001, glyphosate-resistant horseweed was confirmed in Tennessee (Hayes et al., 2002; Mueller et al., 2003). Tennessee weed scientist Dr. Bob Hayes predicted a spread outward from the original resistant population that would rapidly include areas of Arkansas. Indeed, in the first months of 2003, producers in Poinsett, Mississippi, and Craighead counties reported that glyphosate failed to control horseweed in some fields.

The potential for glyphosate resistance in the horseweed population is alarming because horseweed is already a substantial problem in several areas of North America, including conservation-tillage production systems in cotton. Reduced-tillage cotton production has increased dramatically in Arkansas since 1999 (from less than 35% to 60% of the cotton acreage), so this weed, resistant or not, is a focus of preplant and early-season control. Glyphosate is used extensively as a burndown herbicide to control winter and early-spring weeds, including horseweed, before planting a crop in reduced-tillage systems, and its extensive use has apparently been the cause of selection for a resistant population. The widespread use of glyphosate-resistant cotton, soybean, and corn in Arkansas increases the potential for further selection of the resistant biotype. Additionally, horseweed seed is small and easily dispersed by wind, making its spread to adjacent and distant fields imminent.

RESEARCH DESCRIPTION

Suspected glyphosate-resistant plants were collected in May 2003 from three locations in Mississippi and Poinsett counties (Osceola, Lepanto, and Pritchett Corner) to confirm level of resistance. Plants were transplanted into plastic pots and tested for level of resistance in the greenhouse at Fayetteville. Susceptible plants were collected from a susceptible population at Fayetteville and were matched in size to those from the resistant populations. Glyphosate rates of 0, 0.375, 0.75 (labeled 1X rate), 1.5 (2X), 3 (4X), 6 (8X), and 12 (16X) lb ae/A were evaluated in six, single-plant replications from each location. In further greenhouse experiments, seed samples of suspected resistant populations were grown and were tested in a similar manner.

In 2003, field experiments were conducted at Osceola and Fayetteville to screen various herbicides for horseweed control. The experimental area at Osceola contained resistant horseweed, and plots were 12 by 20 feet. Plants were 2 to 10 inches tall when herbicides were sprayed on May 12. A general herbicide screening experiment on susceptible horseweed was established at Fayetteville on 6- by 15-ft plots. Most, but not all, of the herbicides evaluated could potentially be used in cotton. Horseweed was 10 to 20 inches tall when herbicides were sprayed on June 13. Visual ratings for percent controls were taken weekly. Data were subjected to analysis of variance, and means were separated with an LSD at $P = 0.05$.

Common names for herbicides listed in tables and discussion are: Aim, carfentrazone; Blazer, acifluorfen; Buctril, bromoxynil; Caparol, prometryn; Clarity, dicamba; Cobra, lactofen; Command, clomazone; Cotoran, fluometuron; Direx, diuron; Envoke, trifloxysulfuron; FirstRate, cloransulam; Goal, oxyfluorfen; Gramoxone Max, paraquat; Ignite, glufosinate; MSMA (several trade names); Reflex, fomesafen; Roundup WeatherMax, glyphosate; Staple, pyrithiobac; Stinger, clopyralid; Valor, flumioxazin; 2,4-D (several trade names).

RESULTS AND DISCUSSION

The original Osceola population contained plants resistant to 3 lb/A glyphosate (74% control), a resistance factor of 4X, and control was complete with 6 and 12 lb/A. Plants that emerged and were collected and tested a few weeks later from that same population were susceptible to 6 lb/A (58% control), and four out of six plants showed some resistance to 12 lb/A (resistance factor = 16X). The Lepanto plants were also controlled with 6 and 12 lb/A, but had a resistance factor of 4X (contained plants resistant to 3 lb/A). The Pritchett Corner plants had a resistance factor of 16X, with control of only 59% from 12 lb/A 27 days after treatment (DAT). Susceptible plants were controlled 100% with glyphosate at 0.75 lb/A and 81% with 0.375 lb/A. Screening of seed samples is ongoing, and at least a 4X resistance has been found in two out of three samples from Crittenden County, the Pritchett Corner sample from Mississippi County, and a sample from Greene County. A few plants of those populations survived the 8 and 16X rates of glyphosate.

At Osceola, only Roundup WeatherMax plus 2,4-D controlled horseweed more than 80% at three weeks after treatment 3 WAT (Table 1). Control with Gramoxone Max plus 2,4-D or Caparol was initially above 80% but declined by 3 WAT due to regrowth of plants. Control with MSMA, Gramoxone plus Aim, Roundup WeatherMax plus Aim or Staple, and Aim plus Staple was also poor at 3 WAT.

Because of the late application date at Fayetteville, environmental conditions for herbicidal activity were excellent. Treatments that controlled horseweed at least 95% six weeks after treatment (WAT) were: Gramoxone Max alone or plus Direx, Buctril, Ignite, MSMA alone or plus Direx, 2, 4-D, Clarity, Roundup Weathermax, and Stinger (Table 2). Control with Envoke and FirstRate was 87 to 89%, respectively. Activity of Clarity, Stinger, and FirstRate was very slow (approximately 70% at 3 WAT), and 2, 4-D was only slightly faster (78% at 3 WAT). However, herbicidal activity of these herbicides continued to increase for another two weeks. It should be noted that the excellent control from some of these herbicides may not be obtained under less favorable environmental conditions. Control was poor (< 20%) with Staple, Blazer, Goal, Cobra, Reflex, Aim, Command, Valor, Caparol, Cotoran, and Direx (Table 3). Hayes et al. (2002) also reported lack of control with Cobra, Goal, Staple, Aim, and Valor applied post-emergence. Some of these herbicides, however, will be tested for potential pre-emergence activity.

PRACTICAL APPLICATION

As a result of these experiments, an extensive field research program has been initiated in 2004. Fifteen experiments have been established in Mississippi, Craighead, and Poinsett counties in farmer cotton fields with problematic glyphosate-resistant horseweed. Others will be established in Fayetteville and Rohwer. Herbicide rates, timings, and application factors (nozzle size, output volume, etc.) will be evaluated for herbicides such as 2, 4-D, Clarity, Ignite, Aim, Envoke, Gramoxone, and Valor, and screening of preemergence and postemergence activity of herbicides evaluated in 2003 will be continued at some locations. Efforts will be concentrated on developing herbicide programs that can be used closer to the time of planting so that resistant horseweed escaping early applications can be controlled before planting without risk of cotton injury.

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Table 1. Control of glyphosate-resistant horseweed three weeks after treatment (WAT) at Osceola, Ark., in 2003.

Herbicide	Rate[z]	Control 3 WAT[y]
	lb/acre	%
MSMA	3	54 bc
Gramoxone+ Aim	0.75+0.025	52c
Gramoxone+Caparol	0.75+0.8	66bc
Roundup WM+Aim	1.00+0.025	59bc
Aim+Staple	0.025+0.047	3d
Gramoxone+2,4-D	0.75+0.7	72 ab
Roundup WM+2,4-D	1.00+0.7	86 a

[z] Rates in lb active ingredient, except for Roundup WeatherMax (WM), which is lb acid equivalent.

[y] Means followed by the same letter do not differ according to LSD (P=0.05).

Table 2. Herbicide and rates controlling glyphosate-susceptible horseweed 87 to 100% under excellent environmental conditions at Fayetteville, Ark., in 2003.

Herbicide and rate	Herbicide and rate
----------rate (lb/A)----------	
Gramoxone Max, 0.75	2,4-D, 0.375
Buctril, 0.5	Clarity, 0.25
Ignite, 0.36	Roundup Weather Max, 0.75
MSMA, 2	Stinger, 0.19
MSMA+Direx, 2+1	Envoke, 0.007
Gramoxone Max+Direx, 0.75+1	First Rate, 0.19

[z] Rates in lb active ingredient, except for Roundup WeatherMax (WM), which is lb acid equivalent.

COTTON RESPONSE TO TRIFLOXYSULFURON IN ARKANSAS

K.L. Smith, J. Branson, M. Kelly, M.M. McClelland, J.L. Barrentine, and O.C. Sparks[1]

RESEARCH PROBLEM

Trifloxysulfuron-sodium, marketed under the brand name Envoke, is mainly used for broadleaf and sedge weed control in cotton. Trifloxysulfuron-sodium causes the leaves of susceptible plants to turn yellow, red, or purple subsequent to application followed by necrosis and death of the growing point. In some instances crop injury may occur. The purpose of this paper is to examine the data collected over the past five years concerning cotton injury due to trifloxysulfuron-sodium in Arkansas, to evaluate the environmental conditions affecting trifloxysulfuron-sodium injury, and to determine the best recommendations for trifloxysulfuron-sodium use on cotton.

BACKGROUND INFORMATION

Trifloxysulfruon (Envoke) is a sulfonylurea herbicide labeled for post-emergence over-the-top or post-directed application in conventional or transgenic (Roundup Ready® or BXN™) cotton. It controls several economically important weeds in cotton, including morningglory (*Ipomoea)* species, non-ALS-resistant pigweed (*Amaranthus)* species, hemp *sesbania* (*Sesbania exaltata)*, sicklepod (*Senna obtusifolia*), and purple and yellow nutsedge (*Cyperus* species) at very low use rates. Cotton injury from over-the-top applications can be of concern to cotton producers, although the symptoms normally dissipate quickly and do not affect yield (Porterfield, 2002). However, more information is needed to determine conditions under which injury may occur.

RESEARCH DESCRIPTION

Two greenhouse studies were conducted in Monticello, AR in 2001. All treatments were sprayed at the 3- to 4- leaf growth stage. Treatments included untreated controls and trifloxysulfuron-sodium (Envoke) sprayed at 0.0063, 0.0094, and/or 0.0142 lb ai/ac Both studies were arranged in a randomized complete block

[1] Extension weed scientist, Southeast Research and Extension Center, Monticello, research specialist, Rice Branch Station, Stuttgart; weed science program tech, Southeast Research and Extension Center, Hamburg; senior research associate, professor and head, and research specialist II, Crop, Soil, and Environmental Sciences Department, Fayetteville, respectively.

design with six replications. The purpose of the first study was to examine injury due to varying environmental conditions—growth chamber versus greenhouse. All plants were grown to the 3- to 4-leaf stage at 85°F in the greenhouse. Four days prior to spraying half of the pots were moved to 50°F growth chamber. Two rates of 0.0094 and 0.0142 lb ai/ac were sprayed at the 3- to 4-leaf growth stage. Subsequent to spraying, half of the greenhouse pots and half of the growth chamber pots were kept at 50°F in the growth chamber for 4 days. The remaining pots were moved back to 85°F greenhouse. Following the 4 days in growth chamber, all plants were grown at 85°F until harvested. Plants were harvested at 20 days after treatment, and dry weights were recorded. The purpose of the second greenhouse study was to examine injury due to greenhouse or growth chamber temperatures in soil at field capacity and flooded conditions. The two temperatures were 50°F and 85°F, and soils were either kept saturated or at field capacity. All plants were treated at the 3-to 4-leaf stage with two rates of trifloxysulfuron-sodium. Plants were harvested at 15 days after treatment, and dry weights were recorded.

FIELD RESEARCH

Thirty-nine field experiments were conducted over the past five years across three locations: Marianna, Fayetteville, and Rohwer. Thirteen experiments evaluated crop response following preemergence applications, 19 early post-emergence (cotyledon to 4 leaf) applications, 15 mid-post (5-6 leaf) applications, and 11 late post-emergence (7 leaf and above) applications. Field studies were conducted on a randomized complete block with four replications a 12.66 ft (4 rows) wide by 30 ft long. Herbicides were applied with a hand-boom at 12 GPA spray volume. Treatments included untreated checks and trifloxysulfuron-sodium (Envoke) sprayed at 0.0024, 0.0047, 0.0063, 0.0071, 0.0094, 0.0118 and/or 0.0142 lb ai/a. LSD statistics were analyzed using SAS program with an alpha=0.05.

RESULTS AND DISCUSSION

The first greenhouse study examined crop response due to trifloxysulfuron-sodium applications and effects of cool versus warm temperatures four days prior to and four days subsequent to application. Cooler temperatures resulted in increased crop injury 5 days after treatment. By 19 DAT, no difference in crop injury existed for any temperature regime (Fig. 1). There was also no difference in dry weights when compared to the control. The second greenhouse/growth chamber study examined injury due to two temperature regimes (cool vs. warm) superimposed upon two moisture regimes (field capacity vs. flooded). At fourteen days after treatment, plants grown under the cooler temperatures had significantly more injury than those grown in warmer temperatures. Saturated field capacity and soil moisture regimes did not appear to have an effect on injury. There were no differences in dry weights when compared to the control.

FIELD RESULTS

Most crop injury occurred following preemergence or early post-emergence applications. In all studies, cotton injury dissipated by 50 days following application. The most severe crop injury observed at each stage is as follows: preemergence 48% (Fig. 2), early post-emergence 70% (Fig. 3), mid-post 30%, and late post-emergence 25%. Yields were not affected by any trifloxysulfuron-sodium injury at any application timing. Although injury ratings were high, no yield differences were seen at any rate at any application timing (Fig. 4). The least amount of injury was seen when trifloxysulfuron-sodium was applied at the mid-post to late-post application timings. Cotton plants generally recovered from injury within three weeks following over-the-top applications.

PRACTICAL APPLICATION

Greenhouse/growth chamber studies were somewhat inconclusive but indicated that cool temperatures may be more detrimental than wet soils. If crop response cannot be predicted, this herbicide may have limited acceptance as a post-emergence over-the-top herbicide.

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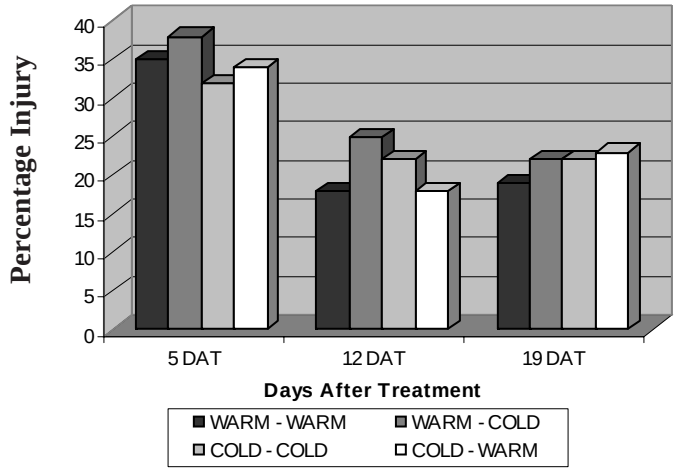

Fig. 1. Percent cotton injury from Envoke (0.0142 lb ai/A) at various days after treatment, as affected by temperature.

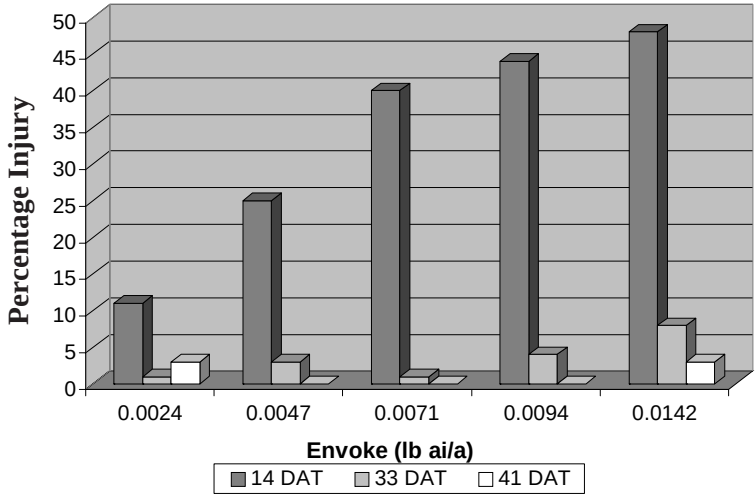

Fig. 2. Percent cotton injury from Envoke pre-applications of five rates at various times after treatment, Rohwer, Ark., in 2000.

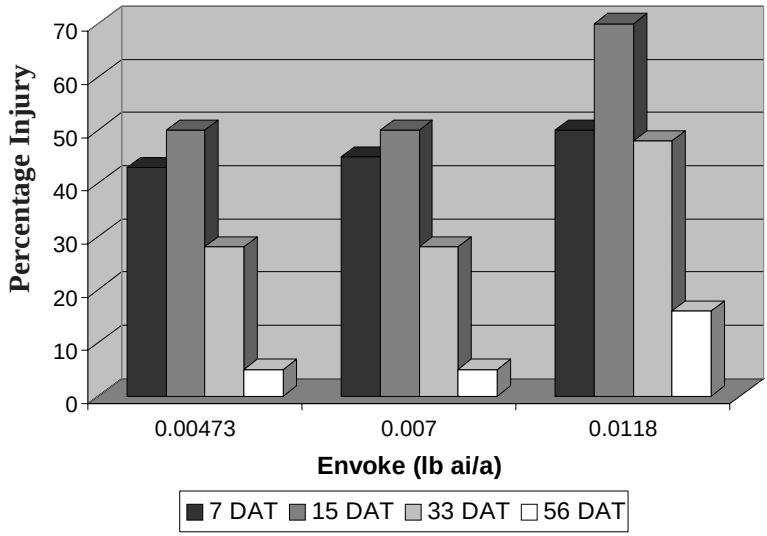

Fig. 3. Percent cotton injury from early post applications of Envoke at various rates; Marianna, Ark., in 2001.

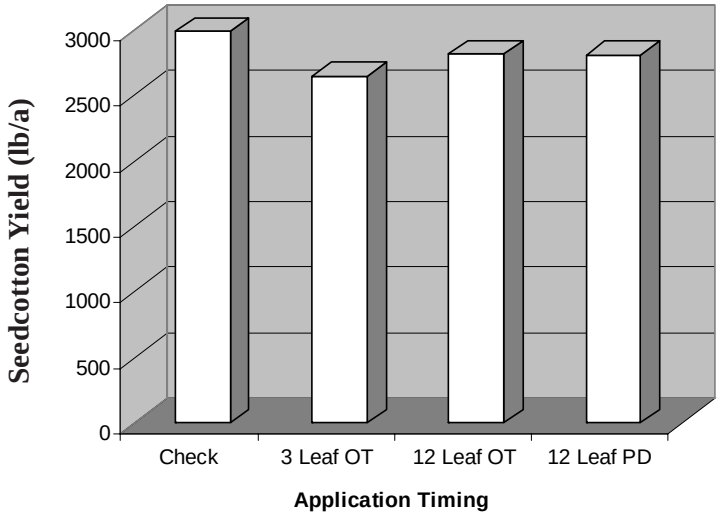

Fig. 4. Seedcotton yields; Marianna, Ark., in 2001.

THE EFFECT OF GLYPHOSATE AND INSECTICIDE TANK MIXTURES ON COTTON BOLLWORM (*HELICOVERPA ZEA*) AND SELECTED WEED SPECIES

O.C. Sparks, J.L. Barrentine, N.R. Burgos, and M.R. McClelland[1]

RESEARCH PROBLEM

The cotton bollworm, *Helicoverpa zea* Boddie (*Lepidoptera: Noctuidae*), is a key insect pest in both corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.). The release of *Bacillus thuringiensis Bt* cotton has reduced the number of insecticide sprays needed for tobacco budworm (*Heliothis virescens*); however, the *Bt* toxin is less effective on *H. zea*. Glyphosate applied over-the-top to current Roundup Ready® cotton cultivars is limited to no later than four-leaf cotton. The pending release of Roundup Ready Flex® cotton in 2006 is expected to allow broadcast applications of glyphosate through flowering. This enhanced tolerance could potentially result in scenarios of the simultaneous need for insect-and weed-management tactics. Therefore, herbicide and insecticide tank mixtures could become more common in cotton, pending the introduction of Roundup Ready Flex cotton.

BACKGROUND INFORMATION

The percentage of acres treated with insecticides in the U.S. from 1995 to 2001 has remained fairly constant; however, more glyphosate and insecticides are applied to cotton than to corn or soybean (Anonymous 2004). Therefore, the likelihood of glyphosate and insecticide tank mixtures is more likely to occur in cotton than corn or soybean. Glyphosate and insecticide tank mixtures would innately reduce fuel use, labor, and equipment wear resulting from a separate pesticide application; however, reduction in application cost could be negated if either the herbicide or insecticide component of the mixture fails.

Herbicide and insecticide combinations can alter the expected response from a herbicide or insecticide treatment applied alone. Herbicide and insecticide interactions have produced results varying from crop injury (Ahrens and Panaram, 1997; Biediger et al., 1992; York and Wilcut, 1993), safening from the herbicide (York et al., 1991), or no effect (Byrd and York, 1988). Acephate, carbaryl, or dimethoate and Staple (pyrithiobac) tank mixtures did not affect entire leaf morningglory control (Jordan et al., 1993). Dimethoate and Poast (sethoxydim)

[1]Research assistant, department head, professor, and senior research associate, respectively, Department of Crop, Soil, and Environmental Sciences.

tank mixtures did not reduce large crabgrass control (Byrd and York, 1988), nor did glyphosate tank mixtures with acephate, cyhalothrin, dimethoate, or imidacloprid antagonize immature and adult thrip control seven days after treatment (Panky et al., 1999). Buctril (bromoxynil) plus azinophos-methyl tank mixtures increased tarnished plant bug control over azinophos alone, and tobacco budworm (*H. virescens*) mortality was increased by Buctril and cyfluthrin tank mixtures (Scott et al., 1996). Still other herbicides, including Fusilade (fluazifop) and Poast may in fact repel insect species (Agnello et al., 1986). The future release of Roundup Ready Flex cotton has imparted interest in evaluating the effect of glyphosate and insecticide tank mixtures on cotton bollworm and weed management.

RESEARCH DESCRIPTION

Weed Control

Greenhouse experiments were conducted in 2003 at the Main Experiment Station, Fayetteville, Arkansas. The study design was completely random with six weed species and four replications. The study was repeated. Seed of pitted morningglory, prickly sida, velvetleaf, hemp *sesbania*, sicklepod, and barnyardgrass were planted 0.6 cm deep into 500-ml plastic pots filled with 400 g of potting soil (Sunshine mix). One to two days after emergence, plants were thinned to one plant per pot and fertilized. Hemp *sesbania*, pitted morningglory, and sicklepod had two leaves, while prickly sida, velvetleaf, and barnyardgrass had three leaves at the time of application. Glyphosate (Roundup WeatherMax) at 0.42 kg acid equivalent/ha, one-half the labeled use rate, was applied alone and in combination with labeled rates of spinosad, 0.075; cyhalothrin, 0.028; methoxyfenozide, 0.34; indoxacarb, 0.1232; cyfluthrin, 0.028; emamectin, 0.0112; cypermethrin, 0.0253; imidacloprid, 0.047; acephate, 0.2; carbaryl, 2.4; and a pre-mixture of imidacloprid/cyfluthrin, 0.079 kg active ingredient/ha. Glyphosate and glyphosate/insecticide tank mixtures were applied in an enclosed spray-chamber at 187 L/ha output volume. Visual weed control was evaluated 1, 3, 7, and 14 days after treatment (DAT) on a scale of 0 to 100, with 0 being no control and 100 being complete control. Plant height of each weed species by treatment was recorded 14 DAT, and plants were harvested for dry weight determination.

Weed control, plant height, and biomass data were subjected to analysis of variance, and means were separated using Dunnett's multiple range test with glyphosate alone at 0.42 kg ae/ha as the control. There was no significant injury at 1 or 3 DAT for hemp *sesbania*, pitted morningglory, prickly sida, velvetleaf, sicklepod, or barnyardgrass; therefore, 7 and 14 DAT data are discussed.

H. zea Response Study

This experiment was conducted as a completely random design with 20 larvae per treatment and was repeated. Neonate larvae reared at the Crawley-Warren Rearing Laboratory were allowed to feed for two days in three 100-ml petri dish filled with approximately 30 ml of prepared diet. Single larvae were transferred from petri dishes into 60-ml diet cups filled with 10 ml of prepared diet using a soft tip, #1 paint brush (to avoid larvae injury). Larvae were placed in a controlled-environment chamber set at 23 ± 2 EC and a 12/12 h day/night regime. *H. zea* larvae and diet were treated when larvae were approximately 20 mm in length and head capsules were 2 mm. *H. zea* survival was evaluated using treatments of 0.25 and 0.5 times the labeled rates of spinosad (0.019 and 0.038 kg ai/ha), cyhalothrin (0.007 and 0.014 kg ai/ha), methoxyfenozide (0.085 and 0.17 kg ai/ha), indoxacarb (0.031 and 0.062 kg ai/ha), cyfluthrin (0.007 and 0.014 kg ai/ha), emamectin (0.00285 and 0.0057 kg ai/ha), and cypermethrin (0.0065 and 0.013 kg ai/ha) applied alone and in combination with glyphosate at 0.84 kg ae/ha. Glyphosate and insecticide tank mixtures were applied in an enclosed spray-chamber at 187 L/ha output volume. Immediately following application, lids were replaced on diet cups and larvae were returned to a controlled-environment chamber set on a 12-h day/night regime at 23 ± 2 EC. Survival of *H. zea* was evaluated on a scale of 0, 0.5, and 1, with 0 indicating death (no movement with successive taps on diet cups), 0.5 indicating suppression (alive without active feeding), and 1 indicating no effect (alive and actively feeding). Survival was visually assessed 24, 48, 72, and 96 hours after treatment (HAT). Average weights per 10 larvae were recorded 96 HAT. *H. zea* survival and larvae weights were subjected to analysis of variance, and means were separated using Fisher's protected LSD at the 5% level of significance. Reduced insecticide rates and large larvae at time of application resulted in similar survival ratings 48 and 96 HAT compared with 24 and 48 HAT; therefore, only 24 and 48 HAT survival data are discussed. Discussion will focus on comparisons of *H. zea* survival within an insecticide treatment with and without the addition of glyphosate.

RESULTS AND DISCUSSION

H. zea survival 24 HAT was less with spinosad and glyphosate tank mixtures than with spinosad alone (Table 1). *H. zea* survival was greater with glyphosate plus cyhalothrin or methoxyfenozide tank mixtures than with cyhalothrin or methoxyfenozide alone; however, *H. zea* larvae surviving glyphosate plus methoxyfenozide tank mixtures were smaller than those treated with methoxyfenozide alone. *H. zea* survival 48 HAT and larvae weights 96 HAT were lower (with glyphosate applied alone) than non-treated larvae. Glyphosate plus emamectin increased control of hemp *sesbania* over that of glyphosate alone (Table 2). Glyphosate plus indoxacarb, emamectin, or cypermethrin reduced velvetleaf height greater than glyphosate alone (Table 3). The glyphosate and carbaryl tank mixture was less effective on hemp *sesbania* (37 vs 60%), pitted morningglory(28

vs 43%), prickly sida (21 vs 50%), sicklepod (23 vs 56%), and barnyardgrass (20 vs 62%) than glyphosate alone.

PRACTICAL APPLICATIONS

Glyphosate and insecticide tank mixtures can decrease or increase pesticide efficacies on certain weed species and *H. zea*; therefore, reduced glyphosate rates and insecticides should be used with caution. Several compounds labeled for over-the-top applications in cotton, including trifloxysulfuron, metolachlor, glufosinate, and glyphosate, have not been fully evaluated with respect to the efficacy of herbicide and insecticide tank mixtures. Future laboratory and field research is needed to evaluate these chemistries in order to make sound scientific recommendations for herbicide and insecticide tank mixtures, especially on species marginally controlled with pesticides. A knowledge base of these interactions could prevent pesticide failures from tank mixtures, saving the producer both time and money.

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Table 1. Survival index[a] with 24 and 48 hours after treatment (HAT) and larvae weight of cotton bollworm 96 HAT, with insecticides with (+) and without (-) glyphosate (gly) at 0.84 kg ae/ha.

	Survival index of larvae[ab]					
	24 HAT		48 HAT		Larvae weight	
Insecticide[c]	(+) gly	(-) gly	(+) gly	(-)gly	(+)gly	(-)gly
kg ai/ha						(g)
Untreated (0)	0.96a-c	0.0417	0.87bc	1.0a	1.20c	4.61a
Spinosad (0.0375)	0.73e-g	0.54e-h	0.88b-d	0.49f-i	0.62f-i	0.63f-h
Spinosad (0.0187)	0.71e-g	0.86cd	0.61d-e	0.58d-f	0.71e-g	1.03cd
Cyhalothrin (0.014)	0.51k-m	0.43lm	0.50f-i	0.33k	0.40jk	0.42jk
Cyhalothrin (0.007)	0.53i-m	0.57h-k	0.37jk	0.65d	0.41jk	0.45h-k
Methoxyfenozide (0.2128)	0.77d-f	0.80de	0.79c	0.61de	0.73ef	0.93d
Methoxyfenozide (0.1064)	0.98ab	0.95a-c	1.0a	0.91ab	1.19c	1.49b
Indoxacarb (0.0616)	0.48k-m	0.55h-l	0.41i-k	0.38jk	0.62f-i	0.63f-h
Indoxacarb (0.0308)	0.51k-m	0.64g-j	0.46g-j	0.41i-k	0.57f-j	0.58f-j
Cyfluthrin (0.014)	0.42m	0.52j-m	0.53e-h	0.44h-j	0.44i-k	0.36k
Cyfluthrin (0.07)	0.54i-m	0.55h-l	0.49f-i	0.53e-h	0.37k	0.45h-k
Emamectin (0.0056)	0.54i-m	0.65g-i	0.58d-f	0.54e-h	0.94d	0.88de
Emanectin (0.0028)	0.66f-h	0.77d-f	0.58d-f	0.55d-g	0.98d	0.70e-g
Cypermethrin (0.01265)	0.58h-k	0.53i-m	0.50f-i	0.51e-i	0.53g-k	0.48h-k
Cypermethri n(0.00633)	0.55h-l	0.55h-l	0.50f-i	0.54e-h	0.54g-k	0.48h-k

[a] Survival index is the average of ratings of dead, supressed, and larvae not affected after treatment; values closer to 1 indicate increased survival.

[b] Means followed by the same range of letters within a specific evaluation period do not differ p (0.05).

[c] Spinsoad (Tracer); cyhalothrin (Karate Z); methoxyfenozide (intrepid); indoxacarb (Steward); cyfluthrin (Baythroid), emamectin (Denim); and cypermethrin (Mustang Max) application rates are 0.5 and 0.25X rates.

Table 2. Percent control of hemp *sesbania*, with glyphosate applied alone at 0.42 kg ae/ha and in tank mixture with selected insecticides at 7 and 14 days after treatment (DAT); plant height and dry weight 14 DAT compared to glyphosate alone.

	Hemp *sesbania*[a]			
Treatment [bc]	7 DAT	14DAT	Plant height	Dry weight
			cm	g
Untreated (0)			20.5b	0.3862a
Glyphosate alone (0.42)	33b	60b	13.0a	0.2647a
Glyphosate + spinsoad(0.075)	33b	58b	13.2a	0.1967a
Glyphosate + cyhalothrin (0.028)	48b	61b	14.5a	0.2613a
Glyphosate + methoxyfenozide (0.16)	37b	58b	14.5a	0.2642a
Glyphosate +indoxacarb (0.1232)	34b	52b	14.8a	0.2741a
Glyphosate + cyfluthrin (0.028)	52b	68b	12.0a	0.2213a
Glyphosate + emamectin (0.0112)	77a	89a	7.5a	0.1314a
Glyphosate + cypermethrin (0.0253)	63a	65b	13.3a	0.2450a
Glyphosate + imidacloprid (0.047)	55b	65b	13.1a	0.2049a
Glyphosate +acephate (0.2)	35b	57b	15.0a	0.2355a
Glyphosate +carbaryl (2.4)	30b	37c	17.1a	0.2667a
Glyphosate + imidacloprid/cyfluthrin (0.079)	47b	60b	13.3a	0.2184a

[a] Means within a column followed by the same letter do not differ from glyphosate applied alone using Dunnett's method.

[b] All pesticide rates, except glyphosate, are in kg ai/ha; glyphosate applied at 0.42 kg ae/ha.

[c] Spinosad (Tracer); cyhalothrin (Karate Z); methoxyfenozide (Intrepid); indoxacarb (Steward); cyfluthrin (Baythroid); emamectin (Denim); cypermethrin (Mustang Max); imidacloprid (Provado); acephate (Orthene); carbaryl (Sevin); and imidacloprid/cyfluthrin (Leverage) are labeled application rates.

Table 3. Percent control of velvetleaf (ABUTH) with glyphosate 0.42kg ae/ha applied alone and in tank mixture with selected insecticides at 7 and 14 DAT; plant height and dry weight at 14DAT compared to glyphosate.

	Velvetleaf[a]			
Treatment [bc]	7 DAT	14DAT	Plant height	Dry weight
			cm	g
Untreated (0)			13.3a	0.6703b
Glyphosate alone (0.42)	32b	26a	13.2a	0.5069a
Glyphosate + spinsoad(0.075)	30b	25a	14.3a	0.5229a
Glyphosate + cyhalothrin (0.028)	32b	28a	14.0a	0.5852a
Glyphosate + methoxyfenozide (0.16)	32b	28a	13.6a	0.6437a
Glyphosate +indoxacarb (0.1232)	47a	43b	10.2a	0.4507a
Glyphosate + cyfluthrin (0.028)	31b	28a	13.8a	0.5092a
Glyphosate + emamectin (0.0112)	37b	48b	9.0b	0.4842a
Glyphosate + cypermethrin (0.0253)	38b	50b	9.2b	0.5309a
Glyphosate + imidacloprid (0.047)	33b	37b	10.8a	0.5321a
Glyphosate +acephate (0.2)	35b	33a	12.2a	0.5512a
Glyphosate +carbaryl (2.4)	21c	25a	14.5a	0.6985b
Glyphosate + imidacloprid/cyfluthrin (0.079)	28b	29a	13.2a	0.7359b

[a] Means within a column followed by the same letter do not differ from glyphosate applied alone using Dunnett's method.

[b] All pesticide rates, except glyphosate, are in kg ai/ha; glyphosate applied at 0.42 kg ae/ha.

[c] Spinosad (Tracer); cyhalothrin (Karate Z); methoxyfenozide (Intrepid); indoxacarb (Steward); cyfluthrin (Baythroid); emamectin (Denim); cypermethrin (Mustang Max); imidacloprid (Provado); acephate (Orthene); carbaryl (Sevin); and imidacloprid/cyfluthrin (Leverage) are labeled application rates.

EFFECT OF PALMER AMARANTH (*AMARANTHUS PALMERI*) SEEDBANK DENSITY ON THE PERFORMANCE OF PENDIMETHALIN AND FLUOMETURON

O.C. Sparks, J.L. Barrentine, N.R. Burgos, and M.R. McClelland[1]

RESEARCH PROBLEM

Palmer amaranth (*Amaranthus palmeri* L.) is one of the most common and difficult-to-control weeds in agriculture (Gossett and Toler, 1999). High growth rate (Sellers, 2003), competitive water use efficiency and light interception (Massinga et al., 2003; Rowland et al., 1999), respiration under stress conditions (Stutte and Weiland, 1978), and high reproductive potential at low plant densities (Bensch et al., 2003) make Palmer amaranth an excellent competitor for crop resources. Palmer amaranth seed production has been estimated to be between 60,000 (Bensch et al., 1999) and 500,000 seed/m^2 (Sellers et al., 2003) depending upon plant density. Abundant seed production, resulting in increased Palmer amaranth seedbank densities, could present pre-emergence (PRE) weed control problems.

BACKGROUND INFORMATION

Increased seedbank populations have been implicated for decreased weed control with soil applied herbicides (Keeley and Thullen, 1991). The effect of seed populations on PRE herbicide efficacy has been investigated in several plant species including ryegrass (*Lolium multiflorum*) (Burrill and Appleby, 1978); soybean (*Glycine max*) (Hoffman and Lavy, 1978; Andersen, 1981; Dieleman et al., 1999); and velvetleaf (*Abutilon theophrasti*) (Dieleman et al., 1999). Seeding rate increases decreased effectiveness of PRE herbicides due to reduced amounts of herbicide available to each plant in the soil-water solution (Andersen, 1981; Burrill and Appleby, 1978; Hoffman and Lavy, 1978; Winkle et al., 1981). Increased weed populations also decrease performance of post-emergence (POST) herbicide programs (Dieleman et al., 1999), probably through inadequate spray coverage of susceptible weed species.

[1] Graduate assistant, professor and head, assistant professor, and Senior Research Associate, respectively, Department of Crop, Soil, and Environmental Sciences Fayetteville.

Therefore, herbicide rate (Hoffman and Lavy, 1978; Winkle et al., 1981) and management levels (Dieleman et al., 1999) may need to be increased with increased seed densities in the soil seedbank. Uncontrolled competition from Palmer amaranth results in substantial yield reductions (Morgan et al., 1997; Rowland et al., 1999). *Amaranthus* species have traditionally been controlled with PRE herbicides, including dinitroanilines and ureas, post-emergence-directed herbicides, and cultivation. The advent of glyphosate-tolerant cotton has allowed for POST over-the-top control of Palmer amaranth in cotton. However, PRE herbicides may still be needed for controlling early infestations of Palmer amaranth, especially in conventional cotton. Pendimethalin and fluometuron efficacy may decrease with increased Palmer amaranth soil seed density. The objective of this research was to evaluate pendimethalin (Prowl) and fluometuron (Cotoran) PRE efficacy as affected by Palmer amaranth soil-seed density.

RESEARCH DESCRIPTION

Greenhouse studies were conducted to evaluate the effects of Palmer amaranth soil seed density on the efficacy of pendimethalin and fluometuron applied PRE. The study design was completely random with eight replications and studies were conducted twice. Styrofoam pots filled with 400 g of silt loam soil were overseeded with seed of Palmer amaranth at 33,000; 66,000; 128,000; 256,000; and 528,000 seed/m^2. These seeding rates cover the range of Palmer amaranth seed production reported by (Sellers et al., 2003) and (Bensch et al., 2003). Seeds where then covered with 100 g of soil resulting in a burial depth of approximately 3 mm. Pendimethalin and fluometuron tank mixtures at rates of 0, 0.28, 0.56, 1.12 (standard field rate), 2.24, and 4.48 kg ai/ha each, were applied PRE to individual pots. Pots were overhead irrigated with a fine mist of water, followed by sub-irrigation. Pots were then subjected to a 14/10 hours, 42/35 °C day/night light and temperature regime. Palmer amaranth seedlings were counted and removed three and six weeks after treatment. Slope estimates of the effect of Palmer amaranth soil density and herbicide on Palmer amaranth survival were compared using 95% confidence intervals. Slope comparisons that differed by more than two times the standard error were considered different. All other data were subjected to analysis of variance, and means were separated using Fishers protected LSD at the 0.05 level of significance.

RESULTS AND DISCUSSION

At all Palmer amaranth soil densities pendimethalin plus fluometuron PRE at 0.28 kg/ha each was less effective than higher rates. Pendimethalin plus fluometuron at 0.56 kg/ha each controlled low Palmer amaranth populations (33,000 to 132,000 seed/m^2) equal to higher herbicide rates. Pendimethalin plus fluometuron rates less than 1.12 kg/ha each controlled Palmer amaranth less than higher rates when Palmer amaranth populations were greater than 132,000 seed/m^2.

Pendimethalin plus fluometuron PRE at 0.28 and 0.56 kg/ha each applied to Palmer amaranth seed densities of 132,000 to 528, 000 seed/m^2 were less effective than rates of 1.12 kg/ha each or greater. Palmer amaranth control with pendimethalin plus fluometuron at 1.12 kg/ha each did not differ from higher rates when Palmer amaranth soil density was 33,000 to 132,000 seed/m^2; however, when the seeding rate was increased from 264,000 to 528,000 seed/m^2, higher herbicide doses were needed. Palmer amaranth escapes were increased by 3- to 7-fold when seeding rate was doubled.

Palmer amaranth decay rates were compared by doubling the standard error for the decay rate estimate to create estimated 95% confidence intervals (Table 2). Decay rates with non-overlapping confidence intervals were considered different. The decay rate was significantly different for only the highest soil seed density of Palmer amaranth 528,000 seed/m^2. Palmer amaranth survival followed a different trend at this seed density (528,000 seed/m^2) than at lower soil seed densities. Decay rates were similar in herbicide rates needed to produce similar reductions in survival; however, the level of survival was usually greater as soil seed density increased.

Optimization of pendimethalin and fluometuron PRE based on zero Palmer amaranth emergence or survival at 3 and 6 WAP from soil seed densities of 33,000; 66,000; 132,000; 264,000; and 528,000 seed/m^2 were 1.12 and 1.12 for 33,000 seed/m^2; 1.23 and 1.23 for 66,000 seed/m^2; 1.45 and 1.68 for 132,000 seed/m^2; 1.68 and 2.46 for 264,000 seed/m^2; and 1.68 and 3.25 kg ai/ha for 528,000 seed/m^2 (Table 3). Pendimethalin plus fluometuron at approximately 1.12 to 1.23 kg/ha each (close to normal field rates) were required when soil densities were between 33,000 and 66,000 seed/m^2. Increasing soil seed densities from 132,000 to 264,000 seed/m^2 required pendimethalin and fluometuron at approximately 1.5 to 2.5 kg/ha each for complete control of Palmer amaranth at 3 WAP (approximately cotyledon- to one-leaf cotton) to 6 WAP (approximately four- to six-leaf cotton). At 528,000 seed/m^2, more than 3 kg/ha of both pendimethalin and fluometuron were required for complete control of Palmer amaranth 6 WAP.

PRACTICAL APPLICATION

Normal field rates of pendimethalin plus fluometuron were as effective in preventing emergence of Palmer amaranth at 3 and 6 WAP at seeding rates of 33,000 through 264,000 seed/m^2. Increased soil seed density required increased rates of pendimethalin and fluometuron. Palmer amaranth soil seed density variation within or between fields should be considered when choosing PRE herbicide programs. PRE herbicide systems, depending upon herbicide rate and soil density of Palmer amaranth, may or may not be effective in controlling Palmer amaranth. Cotton phytotoxicity, a parameter not evaluated in this study, would certainly be a factor, especially at rates greater than 1.12 kg/ha of both pendimethalin and fluometuron. At normal field rates (1.12 kg/ha), in some instances, two-fold increases in soil density increased Palmer amaranth emergence and survival more than five-fold. Future research should consist of multiple regression models to

predict not only Palmer amaranth emergence and survival from different PRE herbicide systems, but also other agronomically important weeds in cotton, considering several factors, including soil type, rainfall, temperature, and microbial enrichment. This information would be a valuable addition to COTMAN or weed-management decision-aid programs.

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Table 1. The effect of pendimethalin and fluoreturon rate and Palmer amaranth seed density (seed m^2) on Palmer amaranth (AMAPA) emergence and survival.

	Palmer amarnath density (seeds/m^2)[a]				
Pendimethalin plus fluometuron	33000	66000	132000	264000	528000
kg ai/ha each	Palmer amaranth emergence and survival /m^2				
0.28	4842 f	10468 de	12343 d	28593 b	36406 a
0.56	625 gh	625 gh	3593 fgh	10781 de	19842 c
1.12	0 h	156 h	781 gh	4218 fg	12031 d
2.24	0 h	0 h	156 h	937 gh	7031 ef
4.48	0 h	0 h	0 h	0 h	0 h

[a] Means followed by the same letter do not differ, (P =0.05).

Table 2. Comparison of Palmer amaranth decay rates (Dr) six weeks after treatment (WAT) over rates of pendimethalin and fluometuron.

		Slope parameters		
			~95% Confidence interval	
AMAPA density	D_r estimate[a]	~Standard error	lower	upper
seeds m^2				
33000	8.2a	2.8	2.6	13.8
66000	11.3a	4.4	2.5	20.1
132000	4.79a	0.932	1.86	6.65
264000	3.449a	0.433	2.58	4.32
528000	1.42b	0.20	0.98	1.82

[a] Slope estimates within a column followed by the same lower-case letter are not significantly different (95% confidence intervals do not overlap).

Table 3. Optimization of equivalent rates of pendimethalin and fluometuron at a specific seedbank population based on complete control of Palmer amaranth at 3 and 6 (WAP).

	Optimization of pendimethalin plus fluometuron rates	
AMAPA density	3 WAP (R^2=0.34) Prob> F=<0.001 Seed 0.076 ±0.022 Herbicide 1.23±0.09	6WAP (R^2=0.65) Prob> F=<0.001 Seed 0.409 ± 0.036 Herbicide -2.31±0.145
seeds/m^2	----------kg ai/ha each----------	
33000	1.12	1.12
66000	1.23	1.23
132000	1.45	1.68
264000	1.68	2.46
528000	1.68	3.25

EXAMINATION OF THE ROLE OF FUNGAL CELL WALL-DEGRADING ENZYMES IN PLANT FUNGAL RESISTANCE

B. Hendrix and J. McD. Stewart[1]

RESEARCH PROBLEM

Transgenic technology has demonstrated its usefulness in weed and insect control, but this technology has yet to expand much beyond these limited, special case scenarios. Along with stringent regulations, the primary limitation preventing expansion into new areas is finding efficacious genes. Fungal pathogens are particularly difficult to control in this regard as these organisms employ many of the same biochemical pathways as plants. One weakness, however, lies in the fungal cell wall, which is susceptible to degradation by a suite of enzymes that attack its structural components. However, the increases in fungal resistance observed by many researchers when fungal cell wall-degrading enzymes are expressed in plant systems may not be the straightforward result of structural degradation. This study examined the mode of action of one fungal cell wall-degrading enzyme, chitosanase.

BACKGROUND INFORMATION

Chitosanase is an enzyme, similar to chitinase, capable of hydrolyzing the á-1, 4-linkages between N-acetyl-D-glucosamine and D-glucosamine residues in a partly acetylated fungal cell-wall chitosan polymer. When attacked by pathogenic fungi, many plants exploit this hydrolytic action as a component of a larger post-attack defense response, but these enzymes may also function in pathogenesis-related (PR) signal transduction. Glucosamine oligomers, released from fungal cell walls after hydrolysis with a chitinase or a chitosanase, are elicitors of plant defense responses such as stomatal closure (Lee et al., 1999), lignification (Moerschbacher et al., 1988; Vander et al., 1998), and PR gene induction (Jabs et al., 1997). The responses elicited by these molecules depend on the length and degree of acetylation of the oligomers released (Vander et al., 1998). More specifically, long oligomers or intact fungal cell walls will cause little or no reaction. However, oligomers that are relatively short (e.g., products of chitosanase hydrolysis) are active elicitors.

Many plant species have been transformed with chitinases (Punja, 2001), and these studies revealed great variability in the antifungal efficacy among

[1]Graduate student and professor, respectively, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

chitinases from different sources. To date, however, there has been only one report of plant transformation with a chitosanase gene (El Quakfaoui et al., 1995), and no reports describing its *in planta* antifungal potential.

RESEARCH DESCRIPTION

The *Paenibacillus* sp. 61724 chitosanase gene was cloned and modified for plant expression (Hendrix et al., 2001). The modified gene and antibiotic selection marker (*npt-II*) were delivered to tobacco (*Nictonia tabacum* L. cv. *Xanthine*) leaf disks via *Agrobacterium tumenfaciens*-mediated transformation. To select the transformed cells, the leaf disks were subjected to kanamycin selection under tissue culture conditions. Over a period of 5-6 weeks, transformed cells regenerated into transformed callus and then transformed plantlets. The putative genetically modified organisms were then tested for transgene integration via Southern blot, transcription via Northern blot, and translation via a leaf-disk lysoplate assay. T1 generation seed were produced from confirmed transformants and screened for enhanced responses to a *Rhizoctonia solani* cell wall preparation by measuring time-course production of hydrogen peroxide and transcriptional induction of three isoforms of phenylalanine ammonia lyase (PAL) by semiquantitative RT-PCR with glyceraldhyde 3-phosphate dehydrogenase as an internal control.

RESULTS AND DISCUSSION

Five transgenic lines, confirmed transformed both by Southern and Northern blot, were selected for further experimentation or seed production. T1 transformants infused with a fungal cell wall preparation produced hydrogen peroxide as early as 2 hours after application and had significant increases in production at 24h. Wild-type plants, however, did not produce significant hydrogen peroxide until the 24h time-point, but it was unclear if this was due to the experimental treatment.

Three isoforms of PAL were tested, but only one isoform (GenBank Accession number X78269) was significantly induced by fungal cell wall application. Similar to hydrogen peroxide production, the induction was observed earlier in the transformed lines than non-transformed plants. These data taken together suggest that cell wall-degrading enzymes play a role in recognition of the invading pathogen, and generate a signal for the plant to mount its natural defenses.

PRACTICAL APPLICATION

Along with the identification of a potential anti-fungal transgene, this study explored the mechanism by which the gene may confer resistance. This information is useful in terms of both basic biology and, perhaps more importantly, in terms of regulation of defensive responses. For a transgenic product to be commercialized, regulators require exact knowledge of how the gene works. This study addressed that issue and cleared the way for future research dealing with the field-based efficacy of the gene with respect to fungal resistance.

ACKNOWLEDGMENTS

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A CDNA-AFLP PROFILE OF COTTON GENES IN RESPONSE TO DROUGHT STRESS

C. Feng and J. McD. Stewart[1]

RESEARCH DESCRIPTION

Water-deficit is a common abiotic stress during the cotton growing season. Water-deficit stress causes a series of negative effects on cotton growth, yield, and fiber quality. Some wild *Gossypium* species, for example, *G. darwinii*, were found to be more tolerant than *G. hirsutum* to drought stress. However, little is known about what is happening at the molecular level, either in cotton or its wild relatives, in response to a water-deficit environment. The technique of cDNA-AFLP is a powerful tool for analyzing gene expression related to environmental stresses.

BACKGROUND INFORMATION

Cotton has a long growing season, during which expose to water-deficit stress is a frequent event. Research has shown that water-deficit stress has diverse effects on cotton. For example, at the morphological level it can inhibit seed germination (Fernandez-Conde et al., 1998) and canopy development; decrease leaf area and number of leaves on sympodial branches (Rosenthal et al., 1987; Pace et al., 1999); reduce the growth, development and distribution of roots (Malik et al., 1979; Pace et al., 1999); cause small bolls and square to shed (McWilliams, 2003); and finally leads to yield loss and poor fiber quality (McWilliams, 2003). At the physiological and biochemical level, water-deficit is associated with decreased leaf transpiration and stomatal conductance, photosynthetic rate, and photosynthetic pigments (Fernandez-Conde et al., 1998). It causes osmolytes such as carbohydrates and malate to accumulate, and also it increases or decreases activities of different enzymes (Pandey et al., 2002) that result in formation of reactive oxygen species leading to oxidative stress (Ratnayaka et al., 2003). However, little is known at the molecular level about the mechanisms available to the cotton plant to cope with water-deficit stress. Nepomuceno et al. (1998) use differential display-PCR (DDRT-PCR) to compare gene expression under drought stress in tolerant and sensitive cultivars. They identified, cloned, and sequenced 46 gene transcripts that were differentially expressed among cultivars and treatments. The sequence information showed that some of those genes were involved in drought-related metabolism. Kosmidou et al. (2002) confirmed that

[1] Research associate and professor, respectively, Department of Crop, Soil, and Environmental sciences, Fayetteville.

five of the identified genes were drought-response genes. The objective of this research was to assess the genetic responses to water-deficit of a wild relative of cotton that showed a very high tolerance to water-deficit.

RESEARCH DESCRIPTION

Gossypium darwinii (AD_5) and *G. hirsutum* (AD_1) Short branch lines were planted in a greenhouse at the University of Arkansas, Fayetteville. Leaf samples were separately collected from the two species under well-watered and water-stressed conditions. RNA was isolated from the four samples with a one-step guanidinium method. First-strand cDNA was synthesized with M-MLV reverse transcriptase and used as template for second-strand synthesis. Then cDNA-AFLP analysis was performed with the Invitrogen AFLP Analysis System I kit (Carlsbad, CA) following the manufacturer's manual with some modifications. The AFLP products were separated electrophoretically through a 6% polyacrylamide gel and visualized with silver staining. The DNA of differentially expressed gene transcripts was purified from the gels cloned into pGEM-T vector and transformed into *E. coli* for cloning. One colony of each clone was sent to Michigan State University for sequencing. The potential functions of cloned genes differentially expressed under water-deficit stress were determined by comparing with sequences in Genbank using the BlastX search. Gene expression was confirmed by reverse northern hybridization. The dot-blotted clones were hybridized with ^{32}P-labled total RNA from *G. darwinii* and *G. hirsutum* under well-watered and water-deficit conditions. RT-PCR was conducted with specific primers designed from sequence information.

RESULTS AND DISCUSSION

Sixty-four primer combinations used to develop the cDNA-AFLP profiles gave 1626 gene transcripts. Of these, about 61% were not related with the water-deficit response; however, about 29% (632) genes appeared to be regulated by water-deficit. Forty-four down-regulated and 72 up-regulated genes in response to drought stress were common to the two species; however, many genes were unique to only one species. Seventy-two down-regulated and 125 up-regulated genes were unique to *G. darwinii*, while 86 down-regulated and 90 up-regulated genes were unique to *G. hirsutum*. Also, drought stress affected the expression of some genes in one species but not the other, i.e., some were up- or down-regulated in *G. darwinii* but constant in *G. hirsutum*, and vice versa. Some genes were regulated in opposite directions by water-deficit in the two species. Figure 1 shows some differentially expressed cDNA-AFLP patterns.

The sequences were obtained for 148 differentially expressed gene transcripts that were responsive to water-deficit stress. Thirty-nine of these had no significant similarity with sequences in Genbank, 8 were homologous to hypothetical protein genes deduced from genomic sequences of other plants, and 101 were homologous to known genes. The known genes could be classified into three categories: 1) cell communication and signal transduction genes, e.g., protein

kinase, putative ethylene-responsive protein gene, and calcium-transporting ATPase; 2) transcriptional factors, e.g., C_2 domain-containing protein, CCCH-type zinc finger protein, and F-box protein; 3) drought-related metabolism genes, e.g., ribulose-1, 5-bisphosphate carboxylase/oxygenase activase, malate synthase, auxin-regulated protein, calcineurin-like phosphoesterase, and fructose-bisphosphate aldolase (Fig.2).

Total RNA from *G. darwinii* and *G. hirsutum* was labeled with ^{32}P and then hybridized with dot-blotted clones to confirm that expression of the selected genes was related to water-deficit stress. Most clones that were up-regulated under water-deficit stress hybridized with RNA from *G. darwinii* and *G. hirsutum* drought-stressed plants, and the clones of genes that were down-regulated under water-deficit stress hybridized with RNA from well-watered *G. darwinii* and *G. hirsutum* plants. In other words, the results were concordant with the cDNA-AFLP patterns. Specific primers were designed for RT-PCR of five of the genes (Fig. 3). Primers for an auxin-regulated protein gene amplified two bands, a large down-regulated fragment and a smaller up-regulated fragment. RT-PCR also confirmed the up-regulated expression pattern for a RING zinc finger protein-like gene, calcium-transporting ATPase, gene and fructose-bisphosphate aldolase gene. Down-regulation of a gene of unknown function was also confirmed by RT-PCR.

The response of cotton to water-deficit stress is very complex with many genes involved. When cotton plants perceive environmental stimuli, such as drought, cell communication and signal transduction initiate transcription factors, which, in turn, increase or decrease the expression of downstream genes. Research on the regulation and expression of cotton genes under water-deficit stress environment should be continued in order to understand the basis of water-deficit tolerance.

PRACTICAL APPLICATIONS

Response and tolerance to water-deficit stress involve a complex set of genetic parameters that include sensing, signal transduction, and response. We have determined that some genotypes are more tolerant of water-deficit than others and are attempting to determine the gene sets that are important in conveying that tolerance. Because of the large number of genes involved in response to an environmental stress, improvement through conventional breeding is nearly impossible. Through identification of the critical genes responsible for rapid sensing and response to stress, e.g., transcription factors, molecular markers can be developed that represent the critical genes. These can be used in marker-assisted selections that will make breeding for stress-tolerance practical.

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Fig. 1. Two profiles of cDNA-AFLP showing a variety of differential gene expressions by *G. darwinii* (AD5) and *G. hirsutum* (SB) under well-watered (w) and water-deficit (d) conditions.

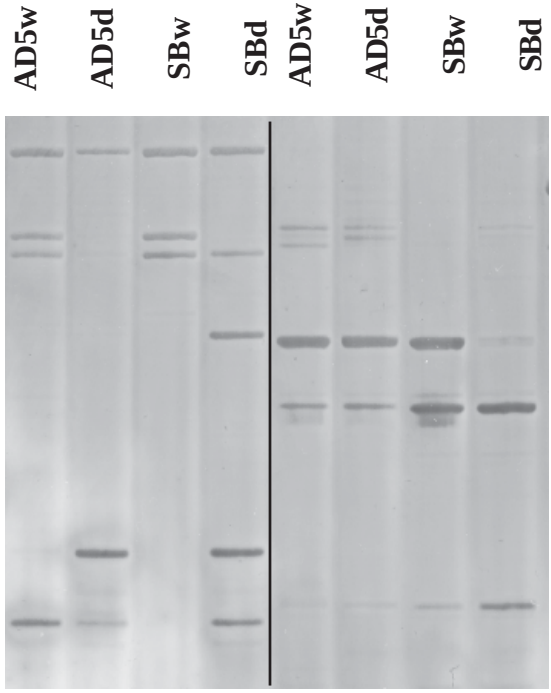


Fig. 2. Potential functions of cloned cotton genes differently expressed under water-deficit stress.

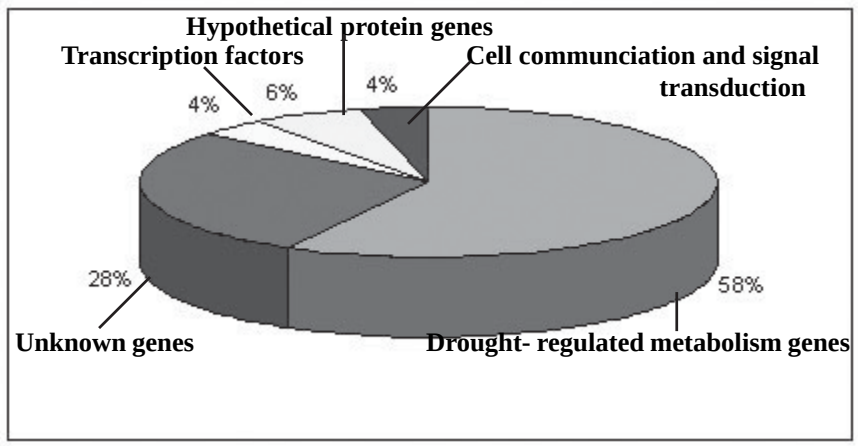
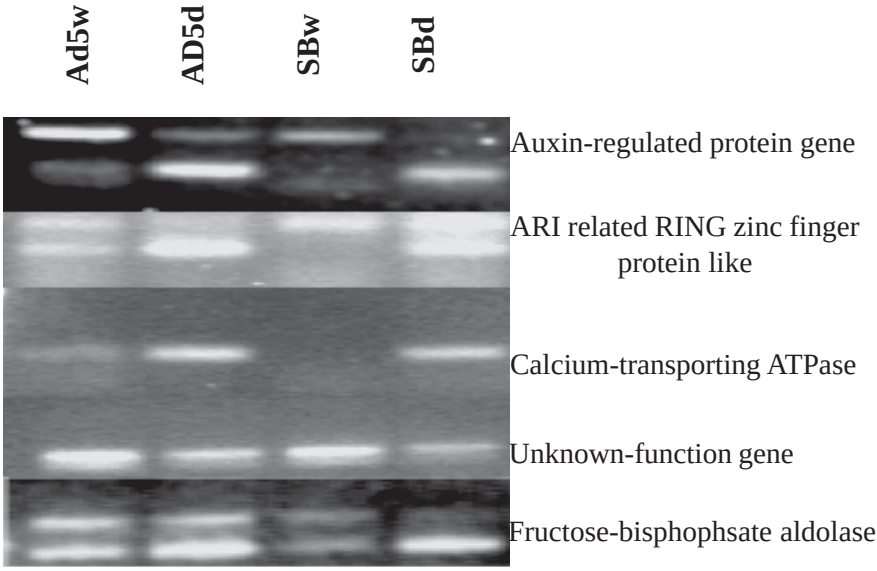


Fig. 3. RT-PCT patterns showing differential expression of 5 genes under drought stress.



TRANSFER OF RENIFORM NEMATODE RESISTANCE FROM DIPLOID COTTON SPECIES TO TETRAPLOID CULTIVATED COTTON

C.A. Avila, J. McD. Stewart, and R.T. Robbins[1]

RESEARCH PROBLEM

The reniform nematode (*Rotylenchulus reniformis*) is a semi-endoparasitic organism in which the female penetrates the root cortex establishing a permanent feeding site (Robinson et al., 1997). It has become a serious threat to cotton (*Gossypium hirsutum* L.) production in Arkansas and the mid-South (Zhao et al., 2000) because yield losses in infested fields may exceed 50% under stress conditions (Smith and Cothren, 1999). The most cost-effective method of pest management is host-plant resistance (Stewart, 1994); however, no commercial cultivars tested to date have shown resistance. Robbins and Stewart (1996) identified a number of sources of resistance within *G. arboreum* (A2), *G. herbaceum* (A1), and *G. longicalyx* (F1). These sources are diploid species; therefore, the material must be genetically enhanced for use in tetraploid cultivated cotton. The objectives of this project are: (1) to develop hybrid materials between resistant reniform nematode diploid cottons and tetraploid cultivated cotton, and (2), to identify molecular markers genetically linked to reniform nematode-resistance gene.

BACKGROUND INFORMATION

Stewart (1994) divided the germplasm resources available for cotton improvement into pools according to genomic affinity. *The primary cotton germplasm pool* contains the genetic resources that will result in direct genetic recombination between the parental genomes in hybrids. All natural *Gossypium* allotetraploids fall within this group. *The secondary pool* includes those genetic resources that require some level of manipulation to obtain fertile hybrids between the source and the cultivated line. However, once fertile hybrids are obtained, recombination potential is high. The A_2, A_1 and F_1 species fall within this group.

Molecular markers are very useful for screening and selection of germplasm within breeding programs (Ford-Lloyd and Painting, 1996). Bulked segregant analysis is a method for rapidly identifying markers linked to any specific gene or genomic region. It involves screening for differences between two pooled DNA samples derived from a segregating population that originated from a single cross (Michelmore et al., 1991). Amplified fragment-length polymorphism (AFLP) provides a very powerful DNA fingerprinting technique for DNAs (Vos et al.,1995)

[1] Graduate assistant and professor, respectively, Department of Crop, Soil, and Environmental Sciences, and professor, Plant Pathology Department, Fayetteville.

where fewer primers should be needed to screen all possible sites (Melcher, 2000) to find a resistant-linked molecular marker.

RESEARCH DESCRIPTION

In order to develop hybrid materials between resistant diploid and tetraploid cotton three basic steps where followed: (1) diploid hybridization, (2) chromosome doubling, and (3) introgression into upland cotton. In the first step, several strategies were pursued simultaneously. A genome, reniform nematode-resistant species were crossed both with D-genome species to produce diploid interspecific hybrids, and with a previously produced hexaploid between *G. hirsutum* (AD_1) and *G. armourianum* ([(AD_1)x$D_{2\text{-}1}$]6X) to produce compatible tetraploid hybrids. A third strategy consisted in crossing a diploid hybrid between *G. longicalyx* (F1) X *G. arboreum* (A2-21) with plants of the D genome and with *G. hirsutum*. The fourth strategy consisted in crossing a previously produced *G. longicalyx* 6X hybrid 2(F_1xAD_1) with D-genome species and upland cotton. The first cross will yield a tetraploid hybrid directly while the second gives a pentaploid that, by recurrent backcrossing with upland cotton, can develop resistance that can be selected through an aneuploid backcross series.

In the second step, colchicine, an anti-mitotic agent, was used to double the number of chromosomes of diploid or triploid hybrids: This was achieved by 1) applying suspension of 1% colchicine in lanolin on the axillary buds of defoliated plant stems; 2) germinating hybrids on 0.8 % agar medium containing 10 ppm of colchicine for 12 to 18 d; and 3) placing hybrid cuttings in solutions at two colchicine concentrations: 10 ppm for 2, 4, 6, 8 10, 15, 20, and 25 d and 20 ppm for 10 and 15 d. Flow cytometry analysis was carried out to determine the ploidy levels of the original and the colchicine-treated hybrids. In the final step, the synthetic tetraploids produced were crossed with upland cotton to transfer the reniform resistance.

To select the bulks for development of molecular markers associated with resistance, 227 plants of an F2 population of the *G. arboreum* hybrid A2-128 x A2-19, 25 plants of A2-128 susceptible parent, and 25 of A2-19 resistant parent were inoculated with 3,300 nematodes, and after 2 months the nematodes were recovered by the sucrose centrifuge-flotation method (Jenkins, 1964) and counted.

RESULTS AND DISCUSSION

Eleven reniform-resistant diploid AD-hybrids were obtained from approximately seven hundred crosses utilizing the approaches described above. Of these eleven crosses, five were from the cross of *G. herbaceum* accession A1-15 and *G. aridum* (A_1-15 x D_4), but these died by fungus infection eighteen days after germinating them in agar containing 10 ppm colchicine. Six hybrids were obtained from the cross of *G. arboreum* accession A2-194 and *G. trilobum* (A_2-194 x D8); upon germination in agar-colchicine solution, the roots were killed on

three plants and they died after 10 days. One plant survived the treatment. Of the remaining two hybrids of A_2-190 x D8, one survived after germination in agar-colchicine solution. No embryo was obtained from the remaining crosses. Thus far, the only synthetic tetraploid plant obtained [2(A_2-194 x D_8)] resulted from the treatment of sixty-three plants (680 axillarys buds, approximately 6 buds per plant) giving a 0.14% efficiency. Flow cytometry analysis indicated that this was a chimeric plant.

Two triple hybrids have been produced, one from a cross of [2(A_2-194 x D_8)] as the pollen donor with the commercial cultivar DP491 and another with Delta Pearl. These hybrids are 4X and are expected to carry the genetic resistance to reniform nematode of the diploid A-genome species.

After screening the F2 population of the hybrid A2-128 x A2-19 for reniform reproduction, a regression line was traced between plant height (y-axis) and pf (x-axis) (pf = number of nematodes in the final population). The height of the resistant plants was not affected by the nematode but the height of the susceptible ones had an inverse relationship with pf, showing that an increase in pf is related with a decrease of plant height. These results were not statistically significant at á = 0.05 but showed a clear trend. To remove the effect of outlier observations, student residuals were calculated, and any observation with a residual equal to or more than two was removed. Finally, twenty plants were selected to form DNA bulks of the 10 most resistant and 10 most susceptible plants, to develop a molecular marker linked to reniform resistance. Additional bulks were made of 10 resistant plants with equal pf mean to the resistant control parent and 10 susceptible plants with pf mean equal to the susceptible control parent, A2-19 and A2-128, respectively. Work to identify useful molecular markers is in progress.

PRACTICAL APPLICATION

The tri-species hybrids that have been produced will be used as germplasm material to introgress the resistance into upland cotton. The molecular markers closely associated with the resistance gene(s) will greatly accelerate selection and introgression of the resistance into elite cultivars, since MAS can be used in place of the laborious and time-consuming nematode reproduction screens on segregating plant populations that are now required.

ACKNOWLEDGMENTS

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INTERACTION BETWEEN THE RENIFORM NEMATODE AND *THIELAVIOPSIS BASICOLA* ON COTTON

C.S. Rothrock, W. S. Monfort, T.L. Kirkpatrick, and K.R. Williams[1]

RESEARCH PROBLEM

In recent years, severe stunting of cotton has been observed early in the growing season in a number of producers' fields. This stunting has been associated with the occurrence of black root rot and nematode problems. Two producers' fields were used in 2003 to investigate the importance of this nematode virgule seedling disease interaction on cotton production.

BACKGROUND INFORMATION

Recent research has demonstrated an important interaction between *Thielaviopsis basicola*, the cause of black root rot, and the root-knot nematode, *Meloidogyne incognita* (Walker et al., 1998; 1999; 2000). This interaction causes dramatic reductions in early-season growth in producers' fields and yield reductions of 21 to 44% have been documented in microplot and field research. The interaction increases the damage caused by the two pathogens by increasing the early-season impact from the nematode and extending the damage from black root rot from the seedling stage to a season-long problem. In 2003, a number of producers' fields were again observed with severe stunting of cotton early in the growing season. Soil samples from two fields indicated that the primary nematode problem in these fields was not the root-knot nematode, but the reniform nematode, *Rotylenchulus reniformis.* Paired plots were established to examine

RESEARCH DESCRIPTION

Paired plots were established by selecting areas of fields where cotton plants were stunted early in the season and adjacent areas that appeared to have normal plant growth. Plots were established in one field in Ashley County and one field in Monroe County. Plots were a minimum of four rows by 40 ft in length, with six replications in each field. Soil from plots were assayed for nematodes, *T. basicola,* and fertility. The severity of black root rot was assessed as root discoloration, 1=no root discoloration to 5=>50% root discoloration, and isolation of the pathogen. Plant growth was monitored throughout the growing season and six plants per plot were harvested for yield.

[1] Professor, and graduate assistant, Department of Plant Pathology, Fayetteville; professor, Southwest Research and Extension Center, Hope; and county extension agent, Cooperative Extension Service, Hamburg, respectively.

RESULTS AND DISCUSSION

Stand did not differ between affected and nonaffected plots at either location (Table 1). Top weight, root weight, and plant height were dramatically reduced early in the season in the affected plots compared to the nonaffected plots (Table 1), with plant height being 23 cm and 12 cm in nonaffected and affected plots and 17 cm and 7 cm in nonaffected and affected plots in Ashley and Monroe Co., respectively. Soil populations of *T. basicola* were similar in both nonaffected and affected plots at both sites (Table 2). However, root disease was less severe in nonaffected plots than affected plots at the Ashley Co. site, the only site where seedling disease severity was assessed (Table 2). Populations of the reniform nematode were 3,106 in nonaffected compared to 12,045 in affected plots in Ashley Co., and 617 in nonaffected compared to 7,922 in affected plots in Monroe cos. per 500cc of soil early in the season (Table 2). Root-knot nematode was present in the field in Ashley Co., but populations were not associated with problem areas in the field. Plant heights were significantly reduced and the first fruiting node delayed in affected plots compared to nonaffected plots for both sites at harvest (Table 3). Seedcotton yields were reduced 19% and 29% in the Ashley and Monroe Co. sites, respectively (Table 3). This compares to seedcotton yield reductions of 33% in 2000 and 21% in 2001 for fields with a root-knot nematode x *Thielaviopsis* problem. Data from the paired plots suggest that fields with a reniform problem have severe early- season stunting in the presence of *T. basicola*. Additional research needs to be conducted to verify that a synergistic interaction takes place between the reniform nematode and *T. basicola.*

PRACTICAL APPLICATION

The interaction of the reniform nematode with other pathogens on cotton emphasizes the importance of being aware of nematode and seedling disease problems in fields so as to adopt management practices to limit losses.

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Table 1. Influence of the reniform nematode and black root rot on early-season plant development.

Parameter	Non-affected	Affected
	Ashley County	
Stand (40ft)	127a1	117a
Top weight (g)	24.1a	4.7b
Root weight (g)	2.4a	0.7b
Plant height (cm)	23.3a	11.5b
	Monroe County	
Stand (40ft)	118a	112a
Top weight	43.3a	10.2b
Root weight	5.1a	1.8b
Plant height (cm)	16.7a	6.6b

[1] Means followed in a row by the same letter are not significantly different, protected LSD (P=0.05).

Table 2. Early-season disease and soil populations.

Parameter	Nonaffected	Affected
	Ashley County	
Thielaviopsis basciola (ppg)	250a[1]	189a
Reniform nematode (500cc)	3,106a	12,045b
Root knot nematode (500cc)	3,030a	909a
Root disease index	3.0b	4.5a
	Monroe County	
Thielaviopsis basciola (ppg)	52a	37a
Reniform nematode (500cc)	617a	7,922a

[1]Means followed in a row by the same letter are not significantly different, protected LSD (P=0.05).

Table 3. Influence of the reniform nematode root rot on late-season plant development.

Parameter	Nonaffected		Affected	Loss
		Ashley County		
Seedcotton yield (g/6 plants	399.5a[1]		321.9a	19.4%
Bolls/plant	12.5a		10.1a	
Plant height (cm)	112.5a		96.0b	
First fruiting node	6.5b		7.3a	
		Monroe County		
Seedcotton yield (g/6 plants	298.0a		211.8a	28.9%
Bolls/plant	11.1a		8.6a	
Plant height (cm)	91.2a		70.8b	
First fruiting node	6.9b		10.2a	

[1]Means followed in a row by the same letter are not significantly different, protected LSD (P=0.05).

RENIFORM NEMATODE CONTROL IN COTTON WITH NEMATICIDES

T.L. Kirkpatrick, J.D. Barham, and R.J. Bateman

RESEARCH PROBLEM

Reniform nematodes continue to increase in incidence and severity in Arkansas each year. Currently these nematodes are managed mainly by the application of nematicides. Nematicides are somewhat effective in improving yield where the nematode is severe, but nematicides are expensive and must be applied each year. By far the most popular nematicide for cotton has been aldicarb (Temik)™ which can be applied at the time of planting or both at-planting and as a sidedress application a few weeks after planting. The soil fumigant 1, 3-dichloropropene (Telone II) has been used very effectively in other states for nematode control, but little work has been done in Arkansas. In addition, Telone II has only been applied in conventionally tilled systems because the material must be sealed into the soil by a bedding operation. Information is needed both on the most efficacious methods of applying Temik and on the efficacy of application of Telone II in cropping systems other than conventional tillage.

BACKGROUND INFORMATION

Field trials conducted during the last seven years in Arkansas indicate that a significant increase in yield occurs in most years where aldicarb is applied, although the degree of yield increase that is achieved varied considerably (T.L. Kirkpatrick, unpublished). Telone II has shown considerable promise for control of the root-knot nematode in southeastern Arkansas in conventionally managed systems. With this approach, the fumigant is applied by injection under each row and the soil is sealed with a raised bed formed immediately after injection. In tests conducted during the last three years, lint yields have been improved in severely infested fields by 150-196 lb/acre with injection of Telone II. There is no data, however, in Arkansas on the efficacy of Telone II for reniform nematode control, nor is there any information on possible uses of Telone II in minimum-tillage systems.

[1] Plant pathologist, research specialist, and extension associate 111, respectively, Southwest Research and Extension Center, Hope.

RESEARCH DESCRIPTION

Field plot trials were established in a reniform nematode-infested commercial cotton field in Jefferson County, Arkansas, in 2003 to compare the effectiveness of application of Temik in-furrow at planting with a combination of in-furrow and sidedress application. The experiment was a randomized complete block with four replications of each treatment. Individual plot size was four rows (38-inch spacing) by 50 feet long. The cultivar Deltapine 555 RB was used in this test and the experiment was planted on 23 May. Field preparation, fertilization, and crop management was performed by the producer according to his normal practices. The sidedress application of Temik was applied on 8 July by knifing the appropriate amount of material into the soil approximately eight inches on either side of each row. Seedcotton was harvested on 4 November from each plot using a plot picker.

The efficacy of Telone II for reniform nematode control was studied in paired strips in producer fields in Monroe County, Arkansas, in 2003 under a minimum tillage system. A Yetter Avenger, designed for minimum tillage systems, was adapted for injection of Telone II and used to apply the material at three gallons per acre under the row in four-row strips through commercial fields that were infested with reniform nematodes. The Telone II was injected approximately two weeks prior to planting. Each strip was approximately one acre in size and an equivalent sized area was left untreated immediately adjacent to each fumigated strip for comparison. Nematode population density was evaluated from all strips six weeks after fumigation, and yield from the strips was collected with a commercial picker equipped with a yield monitor. Lint yield was calculated at 35% seedcotton weight.

RESULTS AND DISCUSSION

Application of Temik did not have a significant (P=0.05) effect on reniform nematode population densities at planting, mid-season, or harvest, or on lint yield (Table 1). Nematode densities were similar where Temik was applied in-furrow at planting at a rate of (5 lb. /acre) or where Temik was applied both in-furrow at planting (5 lb. /acre) and again as a sidedress (5 lb. /acre) at pinhead square, and densities after these treatments were not lower than where DiSyston was applied or where Gaucho-treated seed was used (neither treatment has nematicidal activity). Lint yields were also not affected by application of Temik, although there was an obvious numerical increase in lint where the in-furrow plus the sidedress treatments were applied. It is likely that the variability within this site, both due to nematode distribution and the fact that the experiment was located on one end of the field where irrigation capabilities were limited contributed to the lack of clear differences between treatments.

In Monroe County, fumigation of field length strips in commercial fields had a significant impact on both nematode numbers and on lint yield. Across ten comparisons, nematode numbers were significantly lower where Telone II was applied, and lint yield at the end of the season was 176 lb. /acre greater after fumigation (Table 2).

PRACTICAL APPLICATION

Based on the results of the paired comparisons in Monroe County, it appears that nematode damage to cotton in terms of yield suppression can be significant. Soil fumigation with Telone II in a minimum tillage system using a Yetter Avenger appears promising and should be explored more fully. Although statistical significance was not seen where Temik was applied this year, the numerical improvement in yield with an additional sidedress application implies that in-furrow application of Temik alone may not be sufficient to provide adequate nematode control in some situations.

Table 1. Nematode population densities and lint yield after various soil insecticide and nematicide treatments. Jefferson, County, Ark., in 2003.

	Nematodes/ 500 cm^3			
Treatment	23 May	12 Jun	4 Nov	Lint (lb/acre)
DiSyston 6.5 lb/A[1]	4,829 a[2]	2,418 a	32,102 a	784 a
Gaucho 8 oz/cwt	6,590 a	2,272 a	40,511 a	772 a
Temik 5 lb/ A	5,511 a	2,159 a	26,250 a	783 a
Temik 5lb+5 lb/A[3]	4,722 a	1,307 a	21,932 a	894 a

[1] Materials applied in-furrow at planting.
[2] Numbers in a column followed by the same letter are not significantly different (P=0.05).
[3] 5lb/A applied in-furrow at planting and 5 lb/A applied as a sidedress at pinhead square.

Table 2. Average nematode population density 6 weeks after treatment with Telone II (4 Jun) using a Yetter Avenger and lint yield from 10 paired comparisons. Monroe County, Ark., in 2003.

Treatment	4 Jun	Lint (lb/acre)
No Telone II (control)	17,201 a	914 a
Telone II (3 gal./acre)	2,182 b	1,090 b

[1] Numbers in a column followed by the same letter, are not significantly different (P=0.05).

GLYCOPROTEINS IN THE GELATINOUS MATRIX OF RENIFORM NEMATODE

P. Agudelo, R.T. Robbins, J.B. Murphy, and J. McD. Stewart[1]

RESEARCH PROBLEM

The females of several sedentary plant parasitic nematodes deposit their eggs in a gelatinous matrix. Information about the chemical composition of this matrix is very limited, so its function still remains mostly speculative (Orion, 1995). Some work has been done to partially characterize the composition of the gelatinous matrix of root-knot nematode (*Meloidogyne* spp.) (Bird and Rogers, 1965; Spiegel and Cohn, 1985; Sharon and Spiegel, 1993; Bird and Self, 1995), but no information is available for other nematodes. The reniform nematode, *Rotylenchulus reniformis*, produces a gelatinous matrix similar in aspect to that of the root-knot nematode. However, the infection habit of the reniform nematode female differs from the root-knot nematode, and the matrix does not originate in rectal glands, but in vulval glands. The objective of this study was to test for the presence of glycoproteins in the gelatinous matrix of reniform nematode, using plant lectins.

BACKGROUND INFORMATION

Several proteinaceous components of the gelatinous matrix of root-knot nematode are glycosylated (Sharon and Spiegel, 1993). Glycosylation of nematode proteins has been implicated in host-parasite relationships (Bird and Rogers, 1965; Orion et al., 1987; Orion, 1995) and in protection against microorganisms (Sharon et al., 1993; Orion and Kritzman, 1998; Orion et al., 2001). Various authors suggest the gelatinous matrix acts as a lubricant and as protection against desiccation (Sharon et al., 1993; Orion and Kritzman, 1998; Orion et al., 2001). Geraert (1994) proposed that the gelatinous matrix of root-knot nematodes is "what is left of the plant sap after it has passed through the intestine," and that its function as an egg-sac "is accidental: it happens often because anal and vulval apertures are close together." We do not believe the role of the gelatinous matrix as an egg sac in any of the sedentary nematodes to be accidental. Confirmation of the presence of glycoproteins may be an important step towards the elucidation of the biological function of the gelatinous matrix in reniform nematode.

[1] Graduate assistant, professor, Plant Pathology Department, Fayetteville; professor, Department of Horticulture, Fayetteville; and professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville, respectively.

RESEARCH DESCRIPTION

Rotylenchulus reniformis was monoxenically cultured on tomato (*Lycopersicon esculentum*) cv. Rutgers. Seeds of tomato were surface sterilized by immersing them in 95% ethyl alcohol for three minutes and transferring them into 0.5% sodium hypochlorite for 10 minutes. The seeds were planted directly in sterile clear plastic containers with autoclaved sand and Gamborg's B5 medium. Plants were inoculated one week after emergence. The vermiform stages used as inoculum were washed repeatedly in sterile streptomycin sulfate (10 ppm) solution. The tomato plants were inoculated near the root tip with 0.1 ml of sterile aqueous suspension containing approximately 100 vermiform. The containers were sealed and kept at 28°C with a 12 hour photoperiod. Periodic observations were performed to determine the time when females started producing the gelatinous matrix.

Freshly formed gelatinous matrix was drawn with a pipette and collected in a microcentrifuge tube. Samples were centrifuged at 1000 g for one minute to separate eggs from the matrix. Samples of the supernatant were added to SDS sample buffer (125 mM tris, pH 6.8, 4% SDS, 20% glycerol, and 0.002% bromphenol blue) and mixed with 10% (v/v) b-mercaptoethanol, followed by heating at 90°C for five minutes. Proteins were analyzed after separation by electrophoresis (12% SDS-PAGE) at 200 V for forty-five minutes. The molecular mass of polypeptides in the matrix samples were calculated by comparison with the electrophoretic mobility of Invitrogen See Blue® Plus 2 molecular weight standards.

Total protein extracts separated in SDS-PAGE were electrophoretically transferred at 30 V for 12 h to a polyvinylidene difluoride membrane. After transfer, any reactive sites remaining on the membrane were blocked in a blocking solution (150 mM NaCl, 10 mM Tris, pH 7.5, 10% Tween 20%) for 2 h at room temperature. Transferred proteins were incubated separately with peroxidase-labeled lectins (Sigma) from the following plants: soybean (*Glycine max*), wheat (*Triticum vulgaris*), asparagus pea (*Tetragonolobus purpureus*), winged bean (*Psophocarpus tetragonolobus*), common gorse (*Ulex europeaus*), castor bean (*Ricinus communis*), and *Griffonia simplicifolia*. Blocked membranes were incubated with the lectins [2mg/ml Tris-buffered saline (TBS), pH 7.4, containing 0.1% bovine serum albumin (BSA) for 1 hour at room temperature, and then washed three times with TBS containing 0.1% BSA. To visualize labeling, 4-chloro-naphthol was used as a substrate for the linked peroxidase. A gelatinous matrix solution unexposed to lectins was used as a control. The SDS-PAGE gel was stained with Coomasie Blue, after transfer, to detect possible remaining protein fractions. The experiment was repeated three times.

RESULTS AND DISCUSSION

Reniform nematode females started producing abundant gelatinous matrix 18 to 21 days after inoculation. The material could be drawn with a fine pipette

tip, but it was difficult to avoid drawing eggs along with the matrix. Eggs, however, could be separated by centrifugation. Wheat germ agglutinin labelled two protein fractions between 60 and 80 kDa. The other lectins did not react with the matrix proteins. The protein fractions that were labeled could also be detected with Coomasie staining in the polyacrylamide gels and on the membranes after transfer.

Wheat germ agglutinin, which recognizes N-acetylglucosamine moieties, also was found by Sharon and Spiegel (1993) to label glycoproteins present in the gelatinous matrix of root-knot nematode. However, they found that the wheat germ lectin labeled much higher molecular weight proteins (150-200 kDa) of the root-knot gelatinous matrix than we observed for reniform matrix. In their study the lower molecular weight fractions were labeled by soybean and *Ulex europeaus* agglutinins, which in this study did not yield any positive reaction. These results show that the glyconjugation characteristics in these two nematodes are distinct, and indicate the need to test a wider variety of lectins in different genera of nematodes.

The hydrophobicity of the labeled reniform glycoprotein, evidenced by low transfer to the membrane, support the role of the gelatinous matrix as a protectant against desiccation of the eggs and female. However, the readily detectable presence of a proteinaceous component in the gelatinous matrix, and its glycosylation, suggest a greater role of the gelatinous matrix in the life history of reniform nematodes and root-knot nematodes than merely inhibiting desiccation or acting as a physical barrier, as has been suggested (Geraert, 1994; Orion, 1995).

Obtaining information about biological factors that are critical for nematode survival and interaction with the soil environment is essential for the process of identifying potential management strategies for this nematode pest.

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EFFICACY OF SELECTED INSECTICIDES FOR PLANT BUG CONTROL IN ARKANSAS, 2003

G.M. Lorenz, D.R. Johnson, P.R. Smith, W .H. Robertson, J.K. Greene, C.D. Capps, D. Plunkett, B. Harmon, and R. Edmund[1]

RESEARCH PROBLEM

The tarnished plant bug (*Lygus lineolaris*) is a major pest of cotton. The insect causes damage by feeding on plant tissue and can reduce yields if left uncontrolled. The purpose of these trials was to evaluate the effectiveness of various insecticides for the control of tarnished plant bug.

BACKGROUND INFORMATION

Tarnished Plant Bugs are a troublesome pest in cotton (Hollingsworth et al., 1997; Kharboutli et al., 1998; Robbins et al., 1998). Plant bugs feed on a variety of plant fruiting structures such as squares, blooms, and bolls. Typically they damage young squares by puncturing and feeding on the tissue. In white flowers insects will feed on the anthers of the bloom, and the damage will leave the blooms with a dirty appearance. On young bolls they will puncture the boll and damage the lint and seed. This feeding on bolls will leave wart-like scars and causes off-color lint because of the risk of damaged lint quality and the tendency for the Tarnished Plant Bug to cause multiple damages to single bolls. Their ability as adults to move from plant to plant in a field makes the insect an important pest. The purpose of these experiments was to determine the efficacy of various chemicals for plant bug control.

[1]Extension entomologist, Cooperative Extension Service, Blytheville; pest management section leader and ipm coordinator, Coperative Extension Service, Little Rock; extension entomologist, pest management technical support specialist, Southeast Research and Extension Center, Monticello; cotton verification coordinator, Cooperative Extension Service, Little Rock; cooperative extension service agent, Cooperative Extension Service, Pine Bluff; and Dupont field representative, Dupont Agricultural Products, Little Rock, respectivley.

RESEARCH DESCRIPTION

Experiment one was conducted in Lonoke County, Arkansas. The plots used were planted with (*Gossypium hirsutum L.)* Paymaster 1218 BG/RR. Plot size was 4 rows by 50 foot sections with five rows (38" rows). Experimental design was a randomized complete block with 4 replications. On 11 July the plots were mowed and allowed to re-grow. Plots were sprayed with a one-person boom at nine gallons per acre (gpa) using compressed air on 9 September. Observations of plant bugs were made on 12 September and 16 September, using a beat cloth. Each plot was sampled twice for a total of 12 rowfeet.

Experiment two was conducted at the Marianna Cotton Research Station, Lee County, Arkansas. The plots were planted with Sure-Grow 521RR. Plots were sprayed with a John Deere Hi-Cycle 6000 at 9.7 gpa using compressed air. The test was sprayed on 8 August and 22 August. Observations were conducted on 18 August and 28 August, using a beat cloth. Each plot was sampled twice for a total of 12 rowfeet.

RESULTS AND DISCUSSION

Both locations had extremely high plant bug numbers. At 3d post application both the Lonoke and Marianna location had over 100 plant bugs per 12 row feet.

Lonoke

At 3 days after treatment (DAT) all treatments had significantly fewer plant bugs than the untreated check (Table 1.). Steward and KN-128. (An EC formulation of StewardP had significantly lower total plant bugs than Curacron 0.25. By 7DAT, Karate Z .03, Intruder + Vydate, Intruder, and Centric were not statistically different from the check.

Marianna

At 4 DAT all treatments had significantly fewer plant bugs than the untreated check and Bidrin (0.4) had fewer plant bugs than the Vydate + Intruder treatment. At 7DAT all treatments still had significantly lower plant bugs than the untreated check, with the Bidrin treatment having statistically fewer numbers than all three Intruder rates and the Vydate + Intruder treatment.

PRACTICAL APPLICATION

In Boll Weevil eradication areas, Tarnished Plant Bugs have become a major pest of cotton. This study shows the effectiveness of various insecticides of control in Tarnished Plant Bugs.

ACKNOWLEDGMENTS

We thank Laudis Brantly and Sons and the Cotton Branch Experiment Station for their support in these studies.

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Robbins, J.T., F.A. Harris, and R.E. Furr. 1998. Tarnished Plant Bug control in the Mississippi Delta. *In:* Proceedings, Beltwide Cotton Conferences. National Cotton Council, Memphis, Tenn. Pp. 1197-1998.

Table 1. Summary of results of test one showing mean number of Tarnished Plant Bugs per 12 row feet, Lonoke County, Ark., in 2003.

		3 DAT			7 DAT		
Treatment/ Form	Rate lb (AI/acre)	nymphs	adults	TOTALS	nymphs	adults	TOTALS
Steward 1.25SC + COC[3] 99SL	0.09+1.00 PT/A	12.6 d[1]	2.4b	14.96cd	13.5ef	3.5a	16.91de
	0.104+1.00 PT/A	16.3c	4.8ab	21cd	19.8def	3.0a	22.75cde
KN-128 1.25 SC+COC 99SL	0.09+1.00 PT/A	11.8c	2.5b	14.25d	9.8f	4.3a	14de
KN-128 1.25 SC+COC 99SL	0.104+1.00 PT/A	16.8c	3.3ab	20cd	16.8ef	3.5a	20.25de
Vydate C-LV 3.77SL+Asana XL 0.66EC	0.25+0.036	31bc	6.8ab	37.8bcd	23def	4.3a	27.25cde
Bidrin 8EC	0.33	14.3c	5.8ab	20cd	13.8ef	3.0a	16.75de
Diamond 0.83EC	6FL OZ/A	23.5bc	2.3b	25.75cd	11.3ef	3.3a	14.5de
	9FL OZ/A	24bc	2.3b	26.25cd	7.3f	2.8a	10e
Curacron 8EC	0.25	63.8b	7.3ab	71b	40.8c-f	3.0a	43.75b-e
Karate Z 2.08CS	0.03	42.3bc	7.8a	50bcd	73abc	4.8a	77.75ab
UTC		51bc	6.5ab	57.5bcd	93.3a	5.0a	98.25a
Intruder70WP+Vydate 3.77SL+COC 99SL	0.018+ 0.25+ 1.00PT/A	50.5bc	6.3ab	56.8bcd	56.3bcd	4.8a	61abc
Vydate 3.77SL	0.25	40.3bc	6.8ab	47bcd	43c-f	4.3a	47.25b-e
Centric40WG+ Surfactant 90SL	0.05+0.25	23.8bc	7.3ab	31bcd	22def	4.5a	26.5cde
Intruder 70wp+COC	0.037+ 1.00PT/A	48.3bc	6.3ab	54.5bcd	68.8abc	4.0a	72.75ab
	0.05+ 1.00PT/A	51.5bc	7ab	58.5bc	49.3b-e	3.5a	52.75bcd
Centric 40WG+Surfactant 90SL	0.031+0.25	44.8bc	6.3ab	51bcd	71.3abc	5.8a	77ab
UTC		100.5a	7.3ab	107.75a	85.8ab	5.5a	91.25a

[1]Means followed by same letter do not significantly differ (P=0.05)[2] Mean comparisons performed only when ANOVA Treatment P(f) is significant at mean comparison [3] Crop Oil Concentrate

Table 2. Summary of results of test two, showing mean number of Tarnished Plant Bugs per 12 m, Lee County, Ark., in 2003.

Treatments	Plant bug total 4DAT	Plant bug totals 7DAT
#1 Inruder @ 0.05 lb ai/a	40.5bc[1]	10.75b
#2 Intruder @ 0.038 lb ai/a+Crop Oil@ 1pt/a	46.5bc	11.5b
#3 Intruder @ 0.05lb ai/a+Crop Oil 1pt/a	37.25bc	12.0b
#4 Vydate C-LV@.25 lb ai/a	23.75bc	8.25bc
#5 Intruder @ 0.025 lb ai/a +Vydate @ 0.25 lb ai/a	26.25bc	7.75bc
#6 Intruder @ 0.025 ;b ai/a + Vydate @ .25 lb ai/a + Crop Oil @ 1pt/a	51.25b	7.5bc
#7 Vydate @ .33 lb ai/a + Intruder @ 0.05 lb ai/a	37.5bc	11.75b
#8 Centric @ 0.05 lb ai/a	35.75bc	6.25bc
#9 Orthene @ 0.5 lb ai/a	24.5bc	5.5bc
#10 Trimax @ 1.5 oz ai/a	37.25bc	4.5bc
#11Bidrin @ 0.4 lb ai/a	19.0c	2.0c
#12 Untreated Check	101.25a	23.5a

[1]Means followed by same letter do not significantly differ (P=0.05).

EFFICACY OF SELECTED INSECTICIDES FOR CONTROL OF HELIOTHINES IN ARKANSAS, 2003

D.R. Johnson, G.M. Lorenz, W.H. Robertson, P.R. Smith,J.K. Greene, C.D. Capps, and D. Plunkett[1]

RESEARCH PROBLEM

The purpose of this experiment was to examine the effectiveness of selected insecticides for control of Heliothines with selected insecticides. The Heliothine complex is considered a major pest in cotton production. Efficacy trials provide growers up-to-date information on new and traditional insecticides about which of these products achieve the best control of these pests.

BACKGROUND INFORMATION

The Arkansas recommendation for Heliothine control is to use the higher recommended rates when a cotton production area is under heavy Heliothine pressure (Greene, 2003). However, Heliothine resistance to pyrethroid insecticides has been documented several times in the past few years (Payne et al., 2001; Williams,1999). Tank mixing pyrethroids with non-pyrethroids has been shown to be effective in controlling Heliothine populations (Reaper et al., 2002). As a result of resistance to pyrethroid insecticides, many companies have begun to take an interest in non-pyrethroid insecticides. Compounds such as novaluron (Diamond®), indoxacarb (Steward®), and spinosad (Tracer®) have been introduced as a means of controlling the Heliothine complex. When compared to traditional pyrethroids these products tend to be costlier on a per-acre basis. Previous studies have concluded that when tank mixed with a non-pyrethroid, a traditional pyrethroid provides equal control with labeled rates (Reaper et al., 2001). The purpose of this experiment was to compare the effectiveness of pyrethroids, non-pyrethroids, and non-pyrethroids and pyrethroid tank mixes in controlling a heliothine population that existed in a 2003 cotton production area. The insecticides that were applied in this study that are recommended for Heliothine control in the MP144 2003 Insecticide Recommendations for Arkansas (lamda cyhalothrin,applied at low and

[1]Pest management section leader and ipm coordinator, extension entomologist, extension agronomist-cotton, pest management program technician (pest management), extension entomologist, pest management technical support specialist, and cotton verification coordinator, Arkansas Cooperative Extension Service, Little Rock, respectively.

indoxacarb, spinosad esfenvalerate, and the bifenthrin and spinosad mix) were applied to determine their effectiveness. The insecticides that were not recommended for Heliothine control (novaluron and gamma cyhalothirn) were applied at selected rates to establish an effective control range for these insecticides. All subsequent treatments were made according to statewide threshold recommendations (Greene, 2003).

RESEARCH DESCRIPTION

This trial was conducted at Hooker Farms in Jefferson County, Ark., in 2003 inside the Arkansas Boil Weevil Eradication zone. Sure-Grow 521R was planted on May 23, 2003. Plot size was 8 rows (38'') by 50 feet, 25.3 feet wide and 50 feet in length. Plots were arranged in a randomized complete block with four replications. Treatments were applied with a John Deere Hi-Cycle 6000 delivering 8.3 gallons per acre. Treatments (Table 1) were foliar applied on July 9, July 23, and August 4 of 2003. Data were collected randomly from the middle six rows of each plot. Heliothine damage assessments were taken from 25 terminals, 25 squares, 25 blooms, and 25 bolls from each plot. The data were then analyzed using Analysis of Variance and LSD (P=0.05) in the Agricultural Research Manager (ARM) version 6.1.

RESULTS AND DISCUSSION

All treatments had significantly less damage to terminals and bolls compared to the untreated plot (UTC) (Table 1).

Seasonal large larval counts were significantly lower for all treatments compared to the untreated control with the exceptions of Diamond alone and the pyrethroids (Asana and DE-225) alone (Table 2). However, all treatments, with the exception of Asana, had significantly higher yields than the untreated check. DoubleThreat, Karate plus Diamond, and Steward (0.104) were the higher yielding plots in the study.

PRACTICAL APPLICATION

This study was conducted to evaluate the benefits of combination applications of pyrethroids and non-pyrethroids over individual applications of each. The highest yields with the exception of Steward (0.104) occurred with combination applications of a pyrethroid and a non-pyrethroid (Table 2). This supports the theory that combination applications of pyrethroids and non-pyrethroids provide a more effective means of Heliothine control than individual applications of each.

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Table 1. Heliothine Damage Assessment following treatment of cotton with insecticides, Jefferson County Ark., in 2003.

Treatment	(lbs.ai/A)	25 squares average	25 terminals average	25 blooms average	25 bolls average
Diamond (novaluron)	(0.078)	8.00ab[1]	3.50b	4.00ab	3.00b
Diamond (novaluron) Karate Z (lamba cyhalothrin)	(0.039) (0.03)	4.75b	3.00b	2.00b	2.25b
Steward (indoxacarb)	0.104)	3.00b	2.75b	3.00b	3.50b
Steward (indoxacarb) Asana XL (esfenvalerate)	(0.09) (0.036)	4.25b	2.00b	2.50b	1.75b
Double Threat (bifenthrin & spinosad)	(0.067) (0.059)	3.75b	2.25b	2.00b	2.50b
Double Threat (bifenthrin & spinosad)	(0.05) (0.044)	6.50ab	1.50b	1.00b	1.25b
Tracer (spinosad)	(0.067)	5.25ab	3.25b	1.75b	4.25b
Tracer (spinosad) Asana XL (esdenvalerate)	(0.067) (0.036)	6.00ab	3.00b	1.00b	2.00b
De-225 (gamm cyhalothrin)	(0.017)	7.75ab	3.00b	4.00ab	2.50b
Asana XL (esfenvalerate)	(0.036)	8.25ab	4.25b	3.75ab	4.25b
Steward (indoxacarb)	(0.06)	8.75ab	3.25b	1.25b	2.75b
UTC		11.25a	12.75a	6.25a	100.00a

[1] Means followed by same letter not significantly different P value = 0.05.

Table 2. Effect of various insecticides on Heliothine control and cotton yield in Jefferson County, Ark., in 2003.

Treatment	(lbs.ai/A)	Larvae average	eggs average	Harvest (lbs./A) avg. (37% turnout)
Diamond (novaluron)	(0.078)	12.50abc	6.25b	900.92bc
Diamond (novaluron) Karate Z (lamba cyhalothrin)	(0.039) (0.03)	6.25bc	4.75b	942.74abc
Steward (indoxacarb)	(0.104)	4.50c	5.75b	929.34abc
Steward (indoxacarb) Asana XL (esfenvalerate)	(0.09) (0.036)	5.75bc	5.00b	839.47c
Double Threat (bifenthrin & spinosad)	(0.067) (0.059)	6.00bc	5.25b	1061.85a
Double Threat (bifenthrin & spinosad)	(0.05) (0.044)	7.25bc	7.75b	990.89ab
Tracer (spinosad)	(0.067)	8.25bc	5.50b	904.12bc
Tracer (spinosad) Asana XL (esdenvalerate)	(0.067) (0.036)	9.50bc	3.75b	873.05bc
De-225 (gamm cyhalothrin)	(0.017)	12.50abc	7.75b	883.19bc
Asana XL (esfenvalerate)	(0.036)	12.00abc	7.75b	883.19bc
Steward (indoxacarb)	(0.06)	14.00abc	5.25b	866.71bc
UTC		18.25a	13.75a	695.02d

[1] Means followed by same letter not significantly different P value = 0.05.

TEMIK (ALDICARB) SIDEDRESS COMBINATIONS, 2003

G.M. Lorenz, P.R. Smith, D. Plunkett, and W. H. Robertson[1]

RESEARCH PROBLEM

Nematodes, such as reniform and root-knot are major problems in cotton production. Aldicarb, sold as Temik, has been shown to be an effective means of suppressing these and other species of nematodes. The purpose of this study was to apply Temik at various rates and stages of plant development to determine optimum rates and timing of application.

BACKGROUND INFORMATION

Temik has shown to be effective in controlling reniform nematodes . Nematodes, if left untreated, can significantly reduce yields of cotton up to one bale an acre (Burmester and Gazaway, 1998). Therefore, treating nematodes is important to the overall viability of the plant. Most applications of Temik need to be followed with foliar applications of insecticide to reduce late-season pests.

RESEARCH DESCRIPTION

Two studies were conducted in Jefferson Co. in 2003. Each location was identified as having reniform (Ruggeri) or root-knot (Hooker) nematode infestation. Both locations were planted with the variety Stoneville 4892 on May 23. Plot size was 4 rows (38'') by 50 ft. Plot design was a randomized complete block (RCB) with three replications. Initial aldicarb (Temix) applications were made in-furrow at planting at a rate of either 3.5, 3.0, or 7.0 lb production per acre. Subsequent applications of Temik were made at pinhead square with a two row sidedress application, at 5 DAT on 7/lb/A/; not virgule the treatment received a third application which was timed 10 days after the second application. Two treatments received a foliar application of Vydate (Oxamyl) at 0.25 lb ai/A. Vydate was applied at pinhead square plots were machine harvested on November 4, and data were analyzed using ARM 6.1 using AOV (P=0.05).

[1]Extension entomologist,Cooperative Extension Service, Little Rock; estension program technician (pest management), University of Arkansas Cooperative Extension Service, Lonoke; and extension agronomist-cotton, Univeristy of Arkansas Cooperative Extension Service, Little Rock, respectively.

RESULTS AND DISCUSSION

Reniform Nematode Trial

Yields were extremely low in the trial as a result of late planting and irrigation problems. However, in most cases the supplemental sidedress applications had significantly higher yields than the plots that received only an in-furrow or a foliar application of Vydate.

Root-Knot Nematode Trial

Similar to the reniform trial, yields were generally higher in plots receiving a sidedress application over plots that only received an in-furrow application.

These trials are similar to those conducted in previous years which have shown the advantage of sidedress applications for suppression of nematodes.

PRACTICAL APPLICATION

There are very few options available for cotton producers with nematode problems. The proper use and timing of nematicides is essential to obtain adequate suppression of nematodes. Fine tuning of rates and application timing is critical for cotton producers.

ACKNOWLEDGMENTS

We thank Chuck Hooker and James Ruggeri for their cooperation.

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Table 1. Effect of Temik treatments on lint yield[1] at Ruggeri (reniform) and Hooker Farms (RKN).

Treatments	Ruggeri yield	Hooker yield
Temik @ 5 lb/a followed by Temik @ 5 lb/a followed by Vydate @ 0.25 lb ai/a	421.6a	978.1ab
Temik @ 5 lb/a followed by Vydate @ 0.25 lb ai/a	321.0b	935.8ab
Temik @ 5 lb/a	319.4	924.5ab
Temik @ 7.0 lb/a	388.8ab	869.1b
Temik @ 3.5 lb/a followed by Temik @ 5.0 lb/a	370.1ab	1086.1a
Temik @ 3.5 lb/a followed by Temik @ 5.0 lb/a	390.0ab	1025.0ab
Temik @ 5.0 lb/a followed by Temik @ 5.0 lb/a	348.7ab	986.6ab
Temik @ 5.0 lb/a followed by Temik @ 5.0 lb/a	358.3ab	1060.1a
Temik @ 7.0 lb/a followed by Temik @ 7.0 lb/a	423.22a	1064.00a
Temik @ 7.0 lb/a followed by Temik @ 7.0 lb/a	375.8ab	938.00ab
Temik @ 3.5 lb/a followed by Temik @ 5.0 lb/a followed by Temik @ 5.0 lb/a	368.4ab	985.5ab

[1] Using 33% gin turnout.

PERFORMANCE OF DIAMOND (NOVALURON) FOR CONTROL OF HELIOTHINES AND PLANT BUGS, 2003

P.R. Smith , G.M. Lorenz, W.H. Robertson, D. Plunkett, D.R. Johnson, and R. Edmund[2]

RESEARCH PROBLEM

Pyrethroid resistance in the lepidopteran insects has caused an influx of new non-pyrethroid based compounds. One such compound is Diamond® .83 EC (novaluron), an insect growth regulator. This is a newly available compound sold as Diamond. The purpose of this experiment was to test the effectiveness of Diamond with respect to a standard of spinosad (Tracer® 4 L) and cyhalothrin (Karate Z® 2.08 CS) for heliothine control. Significant differences were observed in the performance of Diamond® compared to the standard.

Aside from heliothine activity, Diamond also exhibits control of tarnished plant bugs (*Lygus lineolaris)*. Diamond was tested for efficacy against Tarnished Plant Bugs and was compared to two rates of Steward® 1.25 SC + Crop Oil 99SL; two rates of KN-128 1.25 EC + Crop Oil 99SL; Vydate® C-LV 3.77 SL + Asana® XL 0.66 EC; Bidrin® 8 EC, Curacron® 8EC; Karate® Z 2.08 CS; Intruder® 70WP + Vydate® 3.77SL + Crop Oil 99SL;Vydate® C-LV; two rates of Centric® 40WG + Surfactant 90SL; two rates of Intruder® 70WP + Crop Oil 99SL; and two untreated checks. Significant differences were observed in the performance of Diamond® in relation to the other treatments.

BACKGROUND INFORMATION

Heliothine resistance to pyrethroid insecticides has been documented several times in the past few years (Reaper et. al 2001; Payne et. al 2001; Williams et. al 1999). Tank mixing pyrethroids with non-pyrethroids has shown to be effective in controlling the Heliothine complex (Reaper et. al, 2002). However, due to cost of mixing treatments, producers are looking for more cost-effective stand-alone chemical applications that achieve effective control. The purpose of this study was to examine the feasibility of Diamond® as a non-tank mixed application, compared to a tank mixed application of Diamond® and Karate® Z, and compared to a standard of spinosad and Karate® Z.

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[1] Extension program technician (pest management), Cooperative Extension Service, Little Rock; extension entomologist, Cooperative Extension Service, Blytheville; extension agronomist, cotton verification coordinator, pest management section leader and ipm coordinator, Cooperative Extension Service, Little Rock; and Dupont field representative, Dupont Agricultural Products, Little Rock, respectively.

Tarnished plant bugs are becoming a major problem for Arkansas farmers and other states across the mid-South (Kharboutli et. al 1998). Resistance to widely used classes of insecticides has been reported (Hollingsworth et. al 1995). Pyrethroid resistance has also been documented (Robbins et. al 1998). Because of this it has become necessary to look to new means of Tarnished Plant Bug control. One such method is the use of insect growth regulators to accomplish effective control. One such compound, novaluron (Diamond® 0.83EC), has shown to be effective for control of tarnished plant bugs.

RESEARCH DESCRIPTION

The Heliothine trial was conducted at Hooker Farms in Jefferson County, Ark., in 2003. Sure-Grow 521RR was planted on 23 May. Plot size was 32 rows (38 inch spacing) and 250 feet in length. Plots were set-up in a randomized complete block with three replications. Treatments were made according to statewide threshold recommendations. Treatments were applied with a John Deere Hi-Cycle 6000 with an 8- row boom and 19-inch nozzle spacing. Foliar treatments were made on 8 July, 23 July, and 4 August. Observations were conducted on 11 July, 15 July, 21 July, 28 July, 31 July, 7 August, 13 August. Plots were machine picked on 31 October. Data were collected from random samples of 50 terminals, 50 squares, and 50 blooms. Insect sampling was conducted using a beat-sheet to sample in 4 locations within each plot. Data were analyzed using Agricultural Research Manager version 6 using Analysis of Variance and LSD (P=0.10)

The tarnished plant bug trial was conducted at Brantley Farms in Lonoke County, Ark., in 2003. Paymaster 1218 BG/RR was planted on 6 May. On 11 July the field was mowed and 100lbs/A of nitrogen was applied. The field was allowed to regrow and was subdivided into plots 12.67ft (4 rows) x 25ft. Plot design was a randomized complete block with four replications. Treatments were applied with a one-man boom sprayer using a CO_2 delivery system and Tee-Jet TXVS-6 nozzles with a 9-inch spacing. Operating pressure was 45 pounds per square inch and 9 gallons per acre of volume. Treatments were applied on 10 September. Observations were conducted on 12 September and 16 September. Data were collected from two randomly selected locations within each plot using a beat-sheet for a total of 12 row feet. Data were analyzed using Agricultural Research Manager version 6 using Analysis of Variance and LSD (P=0.10)

RESULTS AND DISCUSSION

Heliothine Trial.

Terminal damage in the standard (Tracer and Karate Z) and the tank mix (Diamond and Karate Z) performed statistically better than all three rate of Diamond. Diamond (0.078) performed statistically better than the two lower rates of Diamond. Diamond (0.058) was better than the low rate (0.03). Seasonal observations of damaged squares (Table 1) indicated no statistical difference between all 5 treatments. The standard and the tank mixed treatments for damaged blooms showed

no statistical difference between both treatments. However, these treatments did perform statistically better than Diamond alone at all rates. The standard (Karate + Tracer) performed statistically better than the other treatments for damaged bolls. The tank mix and the high rate of Diamond performed statistically better than middle and low rates of Diamond. The middle and low rate were not statistically different.

Plant Bug Trial

At 3DAT (days after treatment), all treatments had significantly lower numbers of total plant bugs compared to the untreated check. Curacron (0.25) showed significantly less control of plant bugs compared to all rates of Steward and KN-128 as well as Birdrin, and both Diamond rates. All other treatments were not different from Curacron.

At 7DAT, all treatments with the exception of Centric at 0.031, Intruder+ Vydate, and Karate Z had significantly fewer plant bugs. Numerically, the Steward, Kn-128, Diamond, and Centric (0.05) were the best treatments in the study.

PRACTICAL APPLICATION

Diamond and KN-128 were shown to be highly effective plant bug compounds compared to many of the other treatments and may provide growers with alternatives to planters. While Diamond shows some activity on Heliothines, the question still remains as to how efficacious it will be.

ACKNOWLEDGMENTS

We acknowledge Chuck Hooker and Brantly and Sons for their cooperation with these trials.

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Table 1. Heliothine-damaged plant structures; randomly selected plant from 50 locations in each plot.

Treatment and rate	Damaged terminals	Damaged squares	Damaged blooms	Damaged bolls
Diamond @ 0.039 lb ai/a	37.67a[1]	22.67a	7.33a	13.67a
Diamond @ 0.058 lb ai/a	35.33a	25.67a	7.67a	13.67a
Diamond @ 0.078 lb ai/a	22ab	27a	4.33a	6.33a
Diamond @ 0.039 lb ai/a+ Karate @ 0.018 lb ai/a	15.67b	14.33a	3.33a	7.33ab
Tracer @ 0.067 lb ai/a + Karate @ 0.03 lb ai/a	8.67b	17a	3.33a	2.67b

[1]Means in a column followed by same letter do not significantly differ (P=0.10, Duncan's New MRT). Mean comparisons performed only when ANOV Treatment P(F) is significant

Table 2. Efficacy of various insecticides for control of Tarnished Plant Bugs-counted per two samples of beat sheet per plot for a total of 12.

Treatment/Form	Rate lb (AI/acre)	Plant Bug nymphs (3DAT)	Plant Bug adults (3DAT)	Plant Bug TOTAS (3DAT)	Plant Bug nymphs (7DAT)	Plant Bug adults (7DAT)	Plant Bug TOTALS (7DAT)
Steward 1.25sc+ Crop Oil Concentrate 99SL	0.09+1.00P-T/A	12.6c[1]	2.4b	14.96cd	13.5ef	3.5a	16.91de
Steward 1.25SC+ Crop Oil Concentrate	0.104 +1.00	16.3c	4.8ab	21cd	19.8def	3.0a	22.75cde
Kn-128 1.25 EC+ Crop Oil Concentrate 99SL	0.09+1.00	11.8c	2.5b	14.25d	9.8f	4.3a	14de
Kn-128 1.25 SC+Crop Oil Concentrate	0.104+1.00	16.8c	3.3ab	20cd	16.8ef	3.5a	20.25de
Vydate C-LV 3.77SL+Asasna XL 0.66EC	0.25+0.036	31bc	6.8ab	37.8bcd	23def	4.3a	27.25cde
Bidrin 8EC	0.33	14.3c	5.8ab	20cd	13.8ef	3.0a	16.75de
Diamond 0.83EC	6FLOZ/A	23.5bc	2.3b	25.75cd	11.3ef	3.3a	14.5de
Diamond 0.83EC	9FLOZ/A	24bc	2.3b	26.25cd	7.3f	2.8a	10e
Curacron 8EC	0.25	63.8b	7.3ab	71b	40.8c-f	3.0a	43.75b-e
Karate Z 2.08CS	0.3	42.3bc	7.8a	50bcd	73abc	4.8a	77.75ab
UTC		51bc	6.5ab	57.5bcd	93.3a	5.0a	98.25a
Intruder 70WP+Vydate 3.77SL+Crop Oil Concnetrate 99SL	0.018+ 0.25+1.00 PT/A	50.5bc	6.3ab	56.8bcd	56.3bcd	4.8a	61abc
Vydate 3.77SL	0.25	40.3bc	6.8ab	47bcd	43c-f	4.3a	47.25b-e
Centri 40 WG+Surfactant9-0SL	0.05+0.25	23.8bc	7.3ab	31bcd	22def	4.5a	26.5cde
Inruder 70WP+Crop Oil Concentrate 99SL	0.037+ 1.00 PT/A	48.3bc	6.3ab	54.5bcd	68.8abc	4.0a	72.75ab
Inruder 70WP +Crop Oil Concentrate	0.05+1.00 PT/A	51.5bc	7ab	58.5bc	49.3b-e	3.5a	52.75bcd
Centric 40WG +Surfactant 90SL	0.031+ 0.25	44.8bc	6.3ab	51bcd	71.3abc	5.8a	77ab
UTC		100.5a	7.3ab	107.75a	85.8ab	5.5a	91.25a

[1]Means followed by the same letter do not significantly differ (P=0.05) Duncan's New MRT).

TREATMENT THRESHOLDS FOR STINK BUGS, 2003

J.K. Greene and C.D. Capps[1]

RESEARCH PROBLEM

Predominant phytophagous (plant-feeding) stink bugs in the southeast and much of the mid-South are similar and include the green stink bug, *Acrosternum hilare* (Say), the southern green stink-bug, *Nezara viridula* (L.), and the brown stink bug, *Euschistus servus* (Say). Several other species are part of the plant-feeding stink bug complex but are of less importance. Stink bugs will become more important and challenge current and future efforts concerning cotton insect management. Investigations into alternative monitoring strategies and management tactics for the pest complex are ongoing projects. In 2003, investigations were continued into development of boll-injury-based thresholds for stink bugs.

BACKGROUND INFORMATION

The status of stink bugs as a challenging pest group continues to escalate because of various factors related to reduced reliance on broad-spectrum foliar insecticides. Factors that allow stink bugs to thrive under our current and future production practices include the eradication of the boll weevil, *Anthonomus grandis* Boheman, availability of alternative chemistries for selective control of worm (*Lepidoptera*) pests, established use of transgenic *Bt* cotton, and the recent registration of second-generation *Bt* cultivars, enhanced for controlling worm pests. All of these advances offer significant reductions in broad-spectrum foliar insecticide usage, and stink bugs greatly benefit from the reduction of insecticides traditionally applied for major pest groups, i.e., "coincidental" control of stink bugs has been eliminated. Stink bugs are now recognized as part of an important group of boll-feeding insects, and producers have had to shift to using "intentional" control for their management. Entomologists have been addressing this problem for several years now and have generated some useful information concerning management of stink bugs in cotton (Greene et al., 1999; Greene et al., 2001a, b; Willrich et al., 2002, 2003; Greene and Capps, 2002, 2003).

RESEARCH DESCRIPTION

Plots of DP424BIIRR and SG215B/RR at the Rohwer Branch of the Southeast Research and Extension Center in Desha County, Arkansas (24 rows by 70 ft and 16 rows by 40 ft, respectively) and PM1218B/R at a producer's farm in

[1]Extension entomologist and pest management program technician, University of Arkansas, Cooperative Extension Service, Monticello.

Ashley County, Arkansas (16 rows by 300 ft) were arranged in a randomized omplete block design, with 6-7 treatments and four replications. Twenty-five bolls (50-75% full size, ca. 14 days after white bloom) were collected from each plot weekly and examined for internal symptoms of feeding by stink bugs. A boll was considered damaged if it had at least one internal growth abnormality (cell proliferation) or obvious staining of lint with associated feeding injury to seeds observed. Dicrotophos (Bidrin 8, Amvac, Los Angeles, Calif.) was applied at 0.50 lb [AI]/A to all plots in a treatment at or exceeding the following levels of damaged bolls: 10, 20, and 30% and at a density of 1 bug per 6 ft of row. Additional treatments included a 15% level in Ashley County and an untreated control at both locations. Two or four rows from the center of each plot were harvested by machine. Data were processed using Agricultural Research Manager (ARM) (Gylling Data Management, Inc., Brookings, S.D.), and means were separated using Least Significant Difference (LSD) procedures following significant F tests using Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

During 2003, three fields in southeast Arkansas were established for research addressing boll-injury thresholds for stink bugs. Data from two of the sites located at the Rohwer Experiment Station in Desha County, Arkansas, with identical treatments were pooled for analysis (Fig. 1). At those sites, 2.0-2.5 applications of dicrophos (Bidrin 8) at 0.5 lb (AI)/A at thresholds of 10 and 20% internal boll injury resulted in 260 and 212 lb/ac, respectively, of increases in lint yield when compared with untreated plots. In-field populations were not detected at the threshold of 1 bug per 6 row feet using a shake sheet. These data are similar to those summarized from earlier trials (Greene and Capps, 2003).

When yield increases and insecticide costs were calculated, the 10% level of treatment (followed closely by 20%) yielded the best net return. In these trials, significant populations of tarnished plant bug (TPB), *Lygus lineolaris*, were present for most of the fruiting period and, although treated 2-3 times with insecticide specifically for control of TPB, caused significant injury to small bolls. The benefits of treating earlier for stink bugs at the 10% level of injury undoubtedly resulted in reduced numbers of both TPB and stink bugs and increased returns. At a third location in Ashley County, Arkansas, results were similar as plots protected four times with Bidrin at the 10 and 15% level produced about 100 lb/ac more cotton than plots treated three times at the 20% level. Bolls and yields were significantly affected at 30 and 50% damage levels after 1 or 2 treatments with Bidrin. When populations of boll-feeding bugs were predominantly comprised of stink bugs, cotton with bolls protected at the 20% level of internal injury produced the highest yields and net return (Greene and Capps, 2003). Under conditions of high TPB pressure, coupled with numbers of stink bugs, protection in the 10-20% range of boll injury apparently provided supplemental protection from TPB and resulted in highest yields and net returns. Recommendations in most states include some variation of a boll-injury threshold for stink bugs and other boll-feeding bugs. As

a result of these continuing studies, alternative monitoring and management recommendations are available for stink bugs in cotton.

PRACTICAL APPLICATION

Research with treatment thresholds for stink bugs, based on monitoring internal feeding injury to bolls, supported treatment at the 10-20% rate of injury to mid-sized (ca. 14-d-old) bolls.

ACKNOWLEDGMENTS

We thank Cotton Incorporated and Arkansas cotton producers for support of this work. We also thank the staff at the Southeast Branch Experiment Station, Rohwer Branch, for their assistance, and our workers Joe Belvedresi, Michael Dodson, Brian Lawhon, Heather Jaggers, Greg O'Neal, Keith Sowell, Michael Shepard, Cory Bryant, Randy Dixon, and Jeremy Spurlock for their assistance in helping conduct our research.

DISCLAIMER

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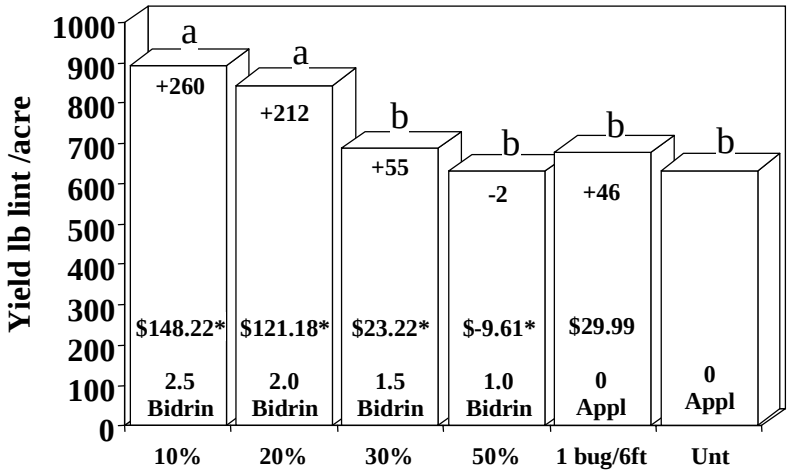

Fig. 1. Two-site average lint yield in 2003 following treatment with dicrotophos (Bidrin 8, avg.# of treatments per treatment) at various thresholds (percentage of internal boll injury or density) for stink bugs. *Net $ gain, calculated with yield gain at $0.65 per lb minus $8.31 per application ($5.31, insecticide plus $3.00, application costs). Treatment bars with a letter in common are not significantly different, P>0.05, LSD = 146.95. *Bt* varieties, 2 sites, 2003.

PHEROMONE TRAPPING OF STINK BUGS, 2003

J.K. Greene and C.D. Capps[1]

RESEARCH PROBLEM

Because stink bugs continue to pose a challenge to current and future efforts concerning cotton insect management, investigations must continue into alternative monitoring strategies and management tactics for the pest complex. Predominant phytophagous (plant-feeding) stink bugs in the Southeast and much of the mid-South are similar and include the green stink bug, *Acrosternum hilare* (Say), the southern green stink bug, *Nezara viridula* (L.), and the brown stink bug, *Euschistus servus* (Say). Several other species are part of the plant-feeding stink bug complex but are of less importance. Pheromone trapping of stink bugs (*Euschistus* spp.) is useful in following in-field populations of stink bugs, but the reduced availability and considerable expense of currently available lures and unavailability of lures for other important species continue to make potential pheromone trapping prohibitive.

BACKGROUND INFORMATION

Stink bugs have become important pests in cotton in recent years because of a tremendous reduction in broad-spectrum insecticide use. Because stink bugs are difficult to detect in cotton, investigations into methods of sampling the pest group are important. A successful pheromone trap would likely have a significant place in our management strategies for the pest complex. Immigration of bugs into fields and population fluctuations might be monitored with trapping techniques. The concept is not new for these insects, but is limited by the lack of effective attractants for the group. The spined soldier bug, *Podisus maculiventris* (Say), has been successfully lured and trapped with a synthetic pheromone (Aldrich et al., 1984), but research on additional stink-bug pheromones has produced few practical lures. One commercially available compound, methyl 2, 4 decadienoate, readily attracts *Euschistus* spp. in some trap designs. The "Florida stink bug trap" has shown potential as an efficient design in pecans (Mizell and Tedders, 1995; Mizell et al., 1997; Yonce and Mizell, 1997). In 2003, we continued investigations into the effectiveness of using this trap and lure combination to observe populations of stink bugs around cotton fields.

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[1] Extension entomologist and pest management program tech, respectively, University of Arkansas, Cooperative Extension Service, Monticello.

RESEARCH DESCRIPTION

Twenty-two traps, modified from Mizell and Tedders (1995) and Greene et al., (2001), were placed in and around cotton fields near Rowher, Arkansas, during 2003. Major components of the traps were corrugated plastic, plastic jars, rubber septa, and synthetic pheromone. Trap tops were made from plastic jars, and trap bases were made from sheets (4' x 8' safety yellow) of 10-mm corrugated plastic board. Lures were placed in the plastic jar top of each trap and consisted of a rubber septum (sleeve stopper, Fisher Scientific, Pittsburgh, PA) treated with 40 ì l of methyl 2, 4-decadienoate, and replaced every seven days. Traps were examined and emptied once a week.

RESULTS AND DISCUSSION

Over a 13-wk sampling period, 2345 stink bugs were captured in 22 traps. Approximately 95% of those trapped were part of the brown stink bug complex, *Euschistus* spp. The majority were *E. servus*, with some *E. tristigmus*, *E. crenator*, and *E. ictericus*. Others included *Thyanta* sp., *A. hilare*, *N. viridula*, and *Oebalus pugnax*.

Weekly trap numbers (Fig. 1) appeared to follow field populations. Capture in pheromone traps declined during July and increased during August and September. Highest trap numbers were obtained during mid- and late September. Highest field populations were detected with shake-sheet procedures during the middle of August and first week of September. The increase in numbers in August and September occurred after a trend for increasing trap capture began in early August. Similar results were observed previously (Greene et al., 2001, Greene and Capps, 2003).

PRACTICAL APPLICATION

Trapping of stink bugs in pheromone traps has potential as a monitoring tool for stink bugs in cotton. Stink bugs can be caught successfully using the combination of a commercially available lure for the brown stink bug complex (*Euschistus* spp.) and a trap designed to visually attract stink bugs. However, effectiveness of the trap is currently hindered by the unavailability of effective lures for other species, such as the green stink bug, *Acrosternum hilare* (Say), and the southern green stink bug, *Nezara viridula* (L.). Trap captures could have some predictive value in terms of population development in the crop, but additional research into this area is necessary.

ACKNOWLEDGMENTS

We thank Cotton Incorporated and Arkansas cotton producers for support of this work. We also thank the staff at the Southeast Branch Experiment Station,

Rohwer Branch, for their assistance, and our workers Joe Belvedresi, Michael Dodson, Brian Lawhon, Heather Jaggers, Greg O'Neal, Keith Sowell, Michael Shepard, Cory Bryant, Randy Dixon, and Jeremy Spurlock for their assistance in helping conduct our research.

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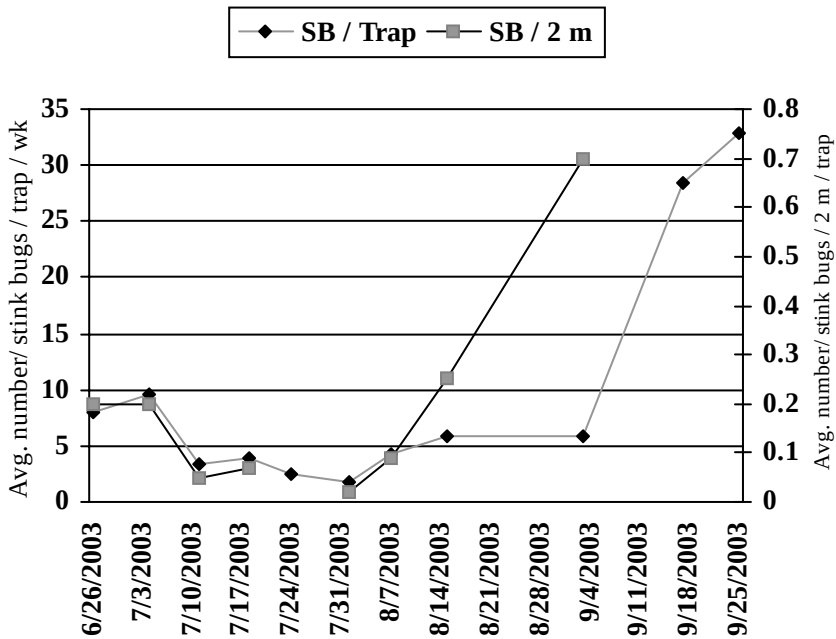
Fig. 1. Weekly average number of stink bugs in pheromone-baited traps and shake sheet samples from cotton near Rohwer, Ark.



EFFICACY OF SELECTED INSECTICIDES FOR CONTROL OF STINK BUGS - 2003

J.K. Greene and C.D. Capps[1]

RESEARCH PROBLEM

Stink bugs continue to pose a challenge to current and future efforts concerning cotton insect management. Predominant phytophagous (plant-feeding) stink bugs in the Southeast and much of the mid-South are similar and include the green stink bug (GSB), *Acrosternum hilare* (Say); the southern green stink bug (SGSB), *Nezara viridula* (L.),;and the brown stink bug (BSB), *Euschistus servus* (Say). Several other species are part of the plant-feeding stink bug complex but are of less importance. In 2003, investigations continued of laboratory bioassays into the effects of several new chemistries compared with those of established materials on the mortality of two important stink bug species (GSB and BSB).

BACKGROUND INFORMATION

The status of stink bugs as a challenging pest group continues to escalate because of various factors related to reduced reliance on broad-spectrum foliar insecticides. Factors that allow stink bugs to thrive under our current and future production practices include the eradication of the boll weevil, *Anthonomus grandis* Boheman, availability of alternative chemistries for selective control of worm (*Lepidoptera*) pests, established use of transgenic *Bt* cotton and the recent registration of second-generation *Bt* cultivars, enhanced for controlling worm pests. All of these advances offer significant reductions in broad-spectrum foliar insecticide usage, and stink bugs greatly benefit from the reduction of insecticides traditionally applied for major pest groups. "Coincidental" control of stink bugs has been eliminated. Stink bugs are now recognized as part of an important group of boll-feeding insects, and producers have had to shift to using "intentional" control for their management. Entomologists have been addressing this problem for several years now and have generated some useful information concerning management of stink bugs in cotton (Greene et al., 1999; Greene et al., 2001a, b; Willrich et al., 2003; Greene and Capps, 2003).

RESEARCH DESCRIPTION

Adults and nymphs of GSB and BSB were collected from soybeans with a sweep net and held overnight in an environmental chamber at 27°C, 60% RH,

[1]Extension entomologist and pest management technical support specialist, Southeast Research and Extension Center, Monticello, respectively.

and a photoperiod of 14:10(l:D)h. They were provided with water and green beans (Harris and Todd 1981), and the following day, adults and fifth instars of each species were placed singly in 30-ml plastic diet cups with a 3-4 cm section of green bean before topical assays.

Doses of each insecticide simulated the concentrations of field-use rates applied at a total volume of 10 gal/A per acre. Mixtures using 1 ml or 1 g of material were made for the insecticides and field-use rates listed in Table 1. To simulate practical efficacy in the field, 1:l of each insecticide mixture was applied to the ventral abdominal segments of each insect. Each bug was returned to its respective diet cup following treatment. A bug was considered dead if in a supine position and no coordinated movement was observed after agitating its cup. Mortality was recorded 24, 48, 72, and 96 hr after treatment.

RESULTS AND DISCUSSION

The predominant species of stink bugs in cotton in southeast Arkansas during 2003 were primarily the green stink bug (GSB), *Acrosternum hilare* (Say); and, to a lesser extent, the brown stink bug (BSB), *Euschistus servus* (Say). The southern green stink bug (SGSB), *Nezara viridula* (L.), was very common in soybeans but was not abundant in cotton until later in the season, therefore its numbers were not sufficient for statistical evaluation in laboratory efficacy trials.

Bidrin and methyl parathion provided excellent control (94-100%) of adults and nymphs of GSB and adults of BSB (Tables 1-3) at the 0.5 lb AI/A rate 24 hr after exposure. The 0.25 lb AI/A rates of both products provided good control (85-97%) of both species at 24 hr. The pyrethroid insecticides applied alone provided variable control (11-100%) of both species after 24 hr (Tables 1-3), but poorest control was demonstrated with BSB (11-78%). Vydate at 0.33 lb AI/A provided good control of both species. When pyrethroids were applied in combination with an organophosphate, a neonicotinoid, or an insect growth regulator (IGR), control (39-100%) was also variable, depending on the grouping. Centric plus Karate and CS-AU-44-JO provided good control of both species, but Karate plus the IGR did not provide acceptable control of BSB when applied topically. As expected, Tracer, a lep-specific material, offered little or no control of both species. Cumulative mortalities for several treatments fluctuated slightly and, in some cases, decreased over time because some bugs recorded as dead apparently recovered from initial "knockdown." These results were consistent with those found previously (Greene and Herzog 2000, Greene and Capps 2003).

PRACTICAL APPLICATION

In laboratory bioassays concerning insecticide efficacy, methyl parathion (Methyl 4E) and dicrotophos (Bidrin 8), standard organophosphates used for control of bug pests, provided superior control (94-100% mortality) of field-collected fifth instars and adults of the green stink bug (GSB), *Acrosternum hilare* (Say), and the brown stink bug (BSB), *Euschistus servus* (Say), at 0.5 lb (AI)/A. Pyrethroid

insecticides alone provided variable results (11-100% 24-hr mortality) due to considerable tolerance by BSB.

ACKNOWLEDGMENTS

We thank Cotton Incorporated, Arkansas cotton producers, AMVAC, Bayer, Cheminova, Control Solutions, Dow AgroSciences, DuPont, FMC, Syngenta, and Crompton/Uniroyal for support of this work. We also thank the staff at the Southeast Branch Experiment Station, Rohwer Branch, for their assistance, and our workers Joe Belvedresi, Michael Dodson, Brian Lawhon, Heather Jaggers, Greg O'Neal, Keith Sowell, Michael Shepard, Cory Bryant, Randy Dixon, and Jeremy Spurlock for their assistance in helping conduct our research.

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Table 1. Cumulative mortality of field-collected adults of the green stink bug, *Acrosternum hilare* (Say), over a four-day interval following exposure to insecticides, (1-ml to ventral abdominal segments) in laboratory bioassays in 2003.

		% cummlative mortality			
Treatment[1] (lb/ [a.i.]/ Acre)	$/ Acre/Application	24 hr	48hr	72hr	96hr
UTC	$0.00	12	30	36	48
Diamond 0.83@0.08	N/A	12	24	27	45
Diamond 0.83@0.039+ Karate 2.08 @0.025	N/A	91	91	97	97
Tracer 4 @ 0.07	$12.75	33	45	58	76
Prolex (gf-231) 1.25@ 0.015	N/A	88	88	91	91
Karate 2.08 @ 0.03	$5.58	88	85	94	97
Mustang Max 0.8 @ 0.02	$4.71	100	97	97	97
Baythroid 2 @ 0.03	$4.93	79	85	94	97
Vydate 3.77 @ 0.25	$4.42	52	61	67	76
Vydate 3.77 @ 0.33	$5.84	85	94	97	97
Centric 40WG @ 0.05	$7.93	79	85	94	85
Bidrin 8 @ 0.25	$2.70	97	100	100	100
Bidrin 8 @ 0.5	$5.40	100	100	100	100
Methyl parathion 4 @ 0.25	$1.83	97	100	100	100
Methyl parathion 4 @ 0.5	$3.66	100	100	100	100
Leverage 2.7 @ 0.079	$11.06	100	100	100	100
Trimax 4 @ 0.0469	$7.58	82	88	91	94
Trimax 4 @ 0.03125+ Bidrin 8 @ 0.25	$7.75	97	97	100	100
Centric 40WG @ 0.03125+ Karate 2.08 @ 0.02	$8.68	94	100	100	100
Cs-AU-JO@ 1qt/acre	N/A	100	100	100	100
Lorsban 4 @ 0.5	$4.75	76	88	91	91

[1] 33 replications were used for each treatment.

Table 2. Cumulative mortality of field-collected nymphs (5th instars) of the green stink bug, *Acrosternum hilare* (Say), over a four-day interval following exposure to insecticides (1-ml to ventral abdominal segments) in laboratory bioassays in 2003.

Treatment[1] (lb/ [a.i.]/ Acre)	$/ Acre/Application	% cummlative mortality 24 hr	48hr	72hr	96hr
UTC	$0.00	25	40	47	57
Diamond 0.83@0.08	N/A	25	51	57	69
Diamond 0.83@0.039+ Karate 2.08 @0.025	N/A	93	94	96	96
Tracer 4 @ 0.07	$12.75	26	39	47	57
Prolex (gf-231) 1.25@ 0.015	N/A	96	97	99	97
Karate 2.08 @ 0.03	$5.58	97	97	97	99
Mustang Max 0.8 @ 0.02	$4.71	96	96	96	97
Baythroid 2 @ 0.03	$4.93	89	92	93	93
Vydate 3.77 @ 0.25	$4.42	88	93	96	96
Vydate 3.77 @ 0.33	$5.84	94	96	96	99
Centric 40WG @ 0.05	$7.93	94	96	97	99
Bidrin 8 @ 0.25	$2.70	93	93	93	93
Bidrin 8 @ 0.5	$5.40	100	100	100	100
Methyl parathion 4 @ 0.25	$1.83	85	97	97	97
Methyl parathion 4 @ 0.5	$3.66	99	100	100	100
Leverage 2.7 @ 0.079	$11.06	100	100	100	100
Trimax 4 @ 0.0469	$7.58	90	88	90	93
Trimax 4 @ 0.03125+ Bidrin 8 @ 0.25	$7.75	100	100	100	100
Centric 40WG @ 0.03125+ Karate 2.08 @ 0.02	$8.68	100	100	100	100
Cs-AU-JO@ 1qt/acre	N/A	99	100	100	100
Lorsban 4 @ 0.5	$4.75	64	90	90	90

[1] 72 replications were used for each treatment.

Table 3. Cumulative mortality of field-collected adults of the brown stink bug, *Euschitus servus* (Say), over a four-day interval following exposure to insecticides (1-ml to ventral abdominal segments) in laboratory bioassays (2003).

Treatment[1] (lb/ [a.i.]/ Acre)	$/ Acre/Application	% cummlative mortality 24 hr	48hr	72hr	96hr
UTC	$0.00	6	22	28	44
Diamond 0.83@0.08	N/A	6	6	6	17
Diamond 0.83@0.039+ Karate 2.08 @0.025	N/A	39	56	67	78
Tracer 4 @ 0.07	$12.75	11	22	39	50
Prolex (gf-231) 1.25@ 0.015	N/A	11	17	28	28
Karate 2.08 @ 0.03	$5.58	39	50	72	78
Mustang Max 0.8 @ 0.02	$4.71	78	72	72	72
Baythroid 2 @ 0.03	$4.93	N/A	N/A	N/A	N/A
Vydate 3.77 @ 0.25	$4.42	78	78	78	78
Vydate 3.77 @ 0.33	$5.84	100	100	100	100
Centric 40WG @ 0.05	$7.93	39	44	50	61
Bidrin 8 @ 0.25	$2.70	94	94	94	94
Bidrin 8 @ 0.5	$5.40	100	100	100	100
Methyl parathion 4 @ 0.25	$1.83	89	89	89	89
Methyl parathion 4 @ 0.5	$3.66	94	100	100	100
Leverage 2.7 @ 0.079	$11.06	78	78	78	72
Trimax 4 @ 0.0469	$7.58	11	6	6	11
Trimax 4 @ 0.03125+ Bidrin 8 @ 0.25	$7.75	94	94	94	94
Centric 40WG @ 0.03125+ Karate 2.08 @ 0.02	$8.68	94	94	94	89
Cs-AU-JO@ 1qt/acre	N/A	89	89	94	94
Lorsban 4 @ 0.5	$4.75	11	33	56	72

[1] 18 replications were used for each treatment.

INSECTICIDE PERFORMANCE EVALUATIONS FOR CONTROL OF TARNISHED PLANT BUG, *LYGUS LINEOLARIS*

J.K. Greene, C.D. Capps, G. M. Lorenz, P.R. Smith, D.R. Johnson, and G. Studebaker[1]

RESEARCH PROBLEM

The tarnished plant bug (TPB), *Lygus lineolaris* (Palisot de Beauvois), has become known as a mid- to late-season pest in addition to an early-season pest in recent years with the addition of *Bt* cotton, completion of the Boll Weevil Eradication Program, and use of lepidopteran-specific insecticides. The expanded prominence of TPB requires continued applied research in the form of insecticide efficacy trials concerning its control.

BACKGROUND INFORMATION

The tarnished plant bug moves from wild hosts as they senesce and cotton begins to fruit. Early-season damage to cotton has been discussed in the literature (Hanny et al., 1977; Smith, 1986: Johnson et al., 1996) where damage from TPB caused square loss resulting in delayed fruiting and crop maturity. TPB will continue to feed on squares and bolls later in the season, causing yield loss and quality reductions through square abortion, boll shed, and reduced fiber quality. The TPB must be controlled early in the season, so that it does not become more difficult to control later in the season as the plant canopy becomes thicker and reduces the effectiveness of insecticide delivery.

RESEARCH DESCRIPTION

Four cotton (*Gossypium hirusutum* L.) tests were planted with Stoneville 4892 B/R on 28 April (Tests I and IV) and 28 May 2003 (Tests II and III) at the Southeast Branch Experiment Station near Rohwer, Arkansas. Plots measured

[1] Extension entomologist, pest management technical support specialist, Southeast Research and Extension Center, Monticello; extension entomologist, Cooperative Extension Service, Little Rock; extension program technician, Cooperative Extension Service, pest management section leader, Little Rock; and extension entomologist, Northeast Research and Extension Center, Keiser, respectively.

eight rows by 40 feet, spaced 38 inches apart, with four replications of each treatment arranged in a randomized complete block design. For the two early-season trials, mustard was seeded in late March on two rows between each eight-row plot to attract plant bugs. Standard fertilization and herbicide practices were followed according to current University of Arkansas Extension recommendations (Chapman, 2000). Insect counts were conducted by sampling 15 ft of row per plot with a small white pan while the cotton was young (< 18 in. tall) and later with a shake sheet (1 m^2) by counting adults and nymphs dislodged into the pan or onto the cloth. Tests I and IV were conducted as early-season plant bug trials, with treatments applied soon after pinhead square. Tests II and III were mid- to late-season trials and applications were made post bloom. Treatments and rates applied are given in Tables 1-4. Data were processed using Agriculture Research Manager (Gylling Data Management, Inc., Brookings, SD), and means were separated using Least Significant Difference (LSD) procedures following significant F tests using Analysis of Variance.

RESULTS AND DISCUSSION

Tests I and II

Most compounds, except Mustang Max, provided significant early-season control of TPB when compared with the untreated control (UTC) across most sample dates (Table 1). This indicated that TPB maintains a tolerance to pyrethroid insecticides similar to results found in other trials (Greene and Capps, 2003; Layton et al., 2003). Yields in plots treated with Centric, Bidrin, Leverage, Trimax, Curacron, and Vydate were statistically higher than those in the UTC, with Centric applications resulting in the highest yields.

In an additional early-season trial, all insecticides provided significant control across most sample dates, with all treatments significantly yielding more than the untreated control (Table 2). Applications of Centric resulted in yields that were numerically higher than those of all other treatments.

Tests III and IV

In the first mid- to late-season trial, all treatments provided significant control two days after the first application (2DAT1) when compared with the UTC (Table 3). Malathion (0.5 lb ai/a) did not significantly differ from the UTC on 4DAT1, and Trimax (0.031 lb ai/a) + Baythroid (0.025 lb ai/a), Malathion (0.5 lb ai/a), and Lorsban (0.5lb ai/a) did not significantly differ from the UTC on 2DAT3. All treatments significantly reduced plant bug numbers on 3DAT2. All treatments except Malathion (0.5 lb a/a) yielded significantly more than the UTC, with Diamond (0.0389 lb a/a) + Karate (0.025 lb a/a), Centric (0.03125 lb a/a) + Karate (0.025 lb a/a), and CS-AU-44-JO yielding the most numerically.

In the second mid- to late-season trial, all treatments provided significant control at 4DAT1 when compared with the UTC (Table 4). All treatments provided significant control of TPB at 3DAT2. Intruder (0.038 and 0.05 lb ai/a) + crop oil were the only (2) treatments that did not yield significantly more than the UTC.

PRACTICAL APPLICATION

In early-season trials, newer chemistries such as novaluron (Diamond) and thiamethoxam (Centric), and newly formulated compounds such as imidacloprid (Trimax), provided adequate control of TPB, as did existing compounds such as acephate (Orthene), dicrotophos (Bidrin), and oxamyl (Vydate). In mid- to late-season trials, new compounds provided enhanced control of TPB when tank mixed with pyrethroids and organophosphates. Experimental compounds, new chemistries such as acetamiprid (Intruder) and Centric, and existing chemistries such as Vydate provided adequate control of TPB. A pyrethroid alone performed poorly in early-season trials reaffirming that pyrethroids should not be used early season for control of TPB.

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DISCLAIMER

The mention of trade names in this report is for informational purposes only and does not imply an endorsement by the University of Arkansas Cooperative Extension Service.

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Table 1. Average number of adult and immature plantbugs per 15-ft sample following insecticide treatment.

Treatment (lb ai/a)	TPB 2DAT1	TPB 7DAT1	TPB 2DAT2	TPB 4DAT2	TPB 7DAT2	TPB 2DAT3	TPB 4DAT3	TPB 8DAT3	Lint Yield
UTC	27.8a-e	20.8abc	11.8abc	10.5a	8.5ab	5.5a	2.3abc	2.8ab	930.5g
Diamond 0.058	33.0abc	4.3d	5.0def	20.d	1.0ef	1.8cd	1.3bc	1.0bcd	977.5efg
Diamond 0.078	37.5a	14.0cd	6.8c-f	3.3cd	0.8f	1.5cd	1.3bc	0.8cd	1072.7c-g
Mustang Max 0.018	30.5 a-d	15.8bc	14.3a	9.5ab	9.3a	2.8bc	4.0a	1.5bcd	986.9d-g
Mustang Max 0.025	35.3ab	25.5ab	13.0ab	8.5ab	6.5abc	4.8ab	2.8ab	3.5a	940.3fg
Centric 0.0375	15.5cde	13.5cd	4.0def	3.0d	4.5cd	1.3cd	0.3c	0.0d	1271.3a
Bidrin 0.33	22.3a-e	20.0abc	1.8f	1.8d	0.5f	0.5d	1.0bc	0.3cd	1083.2b-f
Orthene 97 0.33	32.3abc	17.0abc	3.5ef	2.0d	1.8def	0.0d	0.3c	0.5cd	1060.7c-g
Leverage 0.07	12.8a-e	17.5abc	8.0b-e	3.5cd	4.8cd	1.5cd	1.8bc	2.0abc	1200.6abc
Double Threat	14.3de	26.3a	4.0def	9.0ab	4.3cde	1.8cd	1.3bc	1.3bcd	1023.8d-g
Trimax 0.047	18.8b-e	12.0cd	6.8c-f	4.0cd	5.5bc	1.5cd	0.8bc	2.0abc	1200.6abc
Curacron	26.3a-e	18.3abc	9.3a-d	6.5bc	3.5c-f	2.8bc	0.3c	1.8a-d	1110.3b-e
Vydate 0.33	19.3b-e	20.0abc	1.8f	2.5d	2.0def	0.8cd	0.3c	0.5cd	1128.4a-d

[1] Means followed by same letter do not significantly differ (P=0.05 LSD).

[2] Mean comparisons performed only when ANOVA Treatment p(F) is significant at mean comparison.

Table 2. Average number of adult and immature plant bugs per 15-ft sample following insecticide treatment (Test II).

Treatment (lb aia/a)	TPB 2DAT1	TPB 7DAT1	TPB 2DAT2	TPB 4DAT2	TPB 7DAT2	TPB 2DAT3	TPB 4DAT3	TPB 8DAT3	Yield
UTC	40.5a[1]	17.3a	11.3a	5.8a	3.5a	6.5a	3.3a	1.5a	988.4c
Trimax 0.03125	13.3bc	14.5ab	5.8b	4.0ab	1.8ab	1.5b	0.8b	0.5ab	1265.3b
Trimax 0.0469	24.8b	4.3c	4.8b	2.5b	2.5ab	1.3b	1.3b	0.8ab	1132.1b
Bidrin 0.25	9.5c	8.0bc	3.8b	3.0ab	1.3b	0.5b	0.5b	0.3b	1218.6b
Centric 0.03125	6.3c	9.0abc	3.3b	2.3b	1.0b	1.0b	0.5b	0.8ab	1418.7a

[1] Means followed by same letter do not significantly differ (P=0.05, LSD).
[2] Mean comparisons performed only when ANOVA Treatment p(F) is significant at mean comparison.

Table 3. Average number of adult and immature plant bugs per 15-ft sample following insecticide treatment (Test III).

Treatment (lb ai/a)	TPB 2DAT1	TPB 7DAT1	TPB 2DAT2	TPB 4DAT2	TPB 7DAT2	TPB 2DAT3	TPB 4DAT3	TPB 8DAT3	Lint Yield
UTC	27.8a-c	20.8abc	11.8abc[1]	10.5a	8.5ab	5.5a	2.3abc	2.8ab	930.5g
Diamond 0.058	33.0abc	4.3d	5.0def	20.d	1.0ef	1.8cd	1.3bc	1.0bcd	977.5efg
Diamond 0.078	37.5a	14.0cd	6.8c-f	3.3cd	0.8f	1.5cd	1.3bc	0.8cd	1072.7c-g
Mustang Max 0.018	30.5 a-d	15.8bc	14.3a	9.5ab	9.3a	2.8bc	4.0a	1.5bcd	986.9d-g
Mustang Max 0.025	35.3ab	25.5ab	13.0ab	8.5ab	6.5abc	4.8ab	2.8ab	3.5a	940.3fg
Centric 0.0375	15.5cde	13.5cd	4.0def	3.0d	4.5cd	1.3cd	0.3c	0.0d	1271.3a
Bidrin 0.33	22.3a-e	20.0abc	1.8f	1.8d	0.5f	0.5d	1.0bc	0.3cd	1083.2b-f
Orthene 97 0.33	32.3abc	17.0abc	3.5ef	2.0d	1.8def	0.0d	0.3c	0.5cd	1060.7c-g
Leverage 0.07	12.8a-e	17.5abc	8.0b-e	3.5cd	4.8cd	1.5cd	1.8bc	2.0abc	1200.6abc
Double Threat	14.3de	26.3a	4.0def	9.0ab	4.3cde	1.8cd	1.3bc	1.3bcd	1023.8d-g
Trimax 0.047	18.8b-e	12.0cd	6.8c-f	4.0cd	5.5bc	1.5cd	0.8bc	2.0abc	1200.6abc
Curacron	26.3a-e	18.3abc	9.3a-d	6.5bc	3.5c-f	2.8bc	0.3c	1.8a-d	1110.3b-e
Vydate 0.33	19.3b-e	20.0abc	1.8f	2.5d	2.0def	0.8cd	0.3c	0.5cd	1128.4a-d

[1] Means followed by same letter do not significantly differ (P=0.05, LSD).

Table 4. Average number of adult and immature plant bugs per-15ft sample following insecticide treatment (Test IV).

Treatment (lb aia/a)	TPB 2DAT1	TPB 7DAT1	TPB 2DAT2	TPB 4DAT2	TPB 7DAT2	TPB 2DAT3	TPB 4DAT3	TPB 8DAT3	Yield
UTC	40.5a	17.3a	11.3a [1]	5.8a	3.5a	6.5a	3.3a	1.5a	988.4c
Trimax 0.03125	13.3bc	14.5ab	5.8b	4.0ab	1.8ab	1.5b	0.8b	0.5ab	1265.3b
Trimax 0.0469	24.8b	4.3c	4.8b	2.5b	2.5ab	1.3b	1.3b	0.8ab	1132.1b
Bidrin 0.25	9.5c	8.0bc	3.8b	3.0ab	1.3b	0.5b	0.5b	0.3b	1218.6b
Centric 0.03125	6.3c	9.0abc	3.3b	2.3b	1.0b	1.0b	0.5b	0.8ab	1418.7a

[1] Means followed by same letter do not significantly differ (P=0.05, LSD).

SIMULATING INSECT INJURY WITH EMPHASIS ON STINK BUGS

J.K. Greene and C.D. Capps[1]

RESEARCH PROBLEM

Because true bugs continue to pose a challenge to current and future efforts concerning cotton insect management, we must continue to investigate the potential for yield loss under various circumstances. Excessive terminal and fruit losses from insects, specifically the bug complex (stink bugs or plant bugs), in early-squaring cotton can result in significant loss of canopy structure and yield. Although it is widely documented that plant bugs can and will injure squares and terminal growth, it is unclear if stink bugs injure meristematic tissue and pre-floral buds. Stink bugs are primarily fruit/seed feeders, but their potential capacity to injure terminal growth and squares should caution growers when elevated populations are encountered in young cotton.

BACKGROUND INFORMATION

Stink bugs are an important pest group in cotton because of events related to an overall reduction in broad-spectrum foliar insecticides in recent years. Insects such as tobacco budworm, *Heliothis virescens* (F.), cotton bollworm, *Helicoverpa zea* (Boddie), and boll weevil, *Anthonomus grandis* Boheman, have become minor or "secondary" pests, and bugs (stink bugs and plant bugs) are becoming the primary pest group. As transgenic *Bt* cotton continues to evolve into remarkable technology for control of caterpillars, the gap between bugs and "worms" in importance will widen. Plant bugs and stink bugs will be the most important pest group in cotton in the near future (Greene et al., 1999; Greene et al., 2001a, b; Willrich et al., 2002, 2003; Greene and Capps, 2002, 2003a,b). Predominant phytophagous (plant-feeding) stink bugs in the Southeast and much of the Mid-South are similar and include the green stink bug, *Acrosternum hilare* (Say), the southern green stink bug, *Nezara viridula* (L.), and the brown stink bug, *Euschistus servus* (Say). Several other species are part of the plant-feeding stink bug complex but are of less importance. In 2003, we continued investigations into simulated mechanical injury to terminals, squares, and bolls, with emphasis on bug injury.

[1] Extension Entomologist and pest management technical support specialist, respectively Southeast Research and Extension Center, Monticello.

RESEARCH DESCRIPTION

Plots 4 rows by 30 ft of cotton (*Gossypium hirsutum* L.) cultivar ST4892B/R at the Rohwer Branch of the Southeast Research and Extension Center in Desha County, Arkansas, were arranged in a randomized complete block design with six treatments (boll punctures) and four treatments (terminal and square removals) and four replications. In a test to simulate the mechanical injury caused by pentatomid feeding, bolls (ca. 1-2 weeks from anthesis) were punctured weekly with insect pins (38 x 0.55 mm) by inserting the pointed end into the boll (ca. 0.25 in) ,the middle of one lock through the carpel wall. Bolls from the center two rows were injured in each plot according to the treatment regime (no injury, 10, 20, 30, 50, and 100%). Bolls punctured were tagged with fluorescent flagging tape for identification. Prior to harvest, total bolls and injured (tagged) bolls were counted in each plot to determine actual percentages of simulated injury. Twenty feet of row were hand harvested from the center two rows of each plot.

In a test to simulate injury to terminal growth on young cotton, terminals were hand removed at the 6-7 true leaf stage on 17 June (near pin-head square) by aggressively pinching off terminal growth with thumb and index finger from plants at rates of 25, 50, and 100% in three treatments, with a fourth undamaged/untreated treatment for comparison. In a similar third test, pre-floral buds (squares) were removed weekly for four weeks from young cotton beginning at match-head square on 17 June. Squares were pinched off of plants in a like manner as terminals and at identical rates of 25, 50, and 100%, with an undamaged treatment for comparison. Two rows from the center of each plot, in both the terminal and square removal tests, were machine harvested. All injury simulation studies were protected from natural populations of insect pests by weekly or semi-weekly applications of insecticides.

Data were processed using Agriculture Research Manager (Gylling Data Management, Inc., Brookings, SD), and means were separated using Least Significant Difference (LSD) procedures following significant F tests using Analysis of Variance.

RESULTS AND DISCUSSION

Bolls punctured with insect pins, simulating mechanical feeding injury by stink bugs, at all levels resulted in significant damage and yield losses of up to 345 lb/acre (Table 1). Yields from bolls punctured at all levels (10, 20, 30, 50, and 100% - actually 11.6, 22.2, 32.5, 48.8, and 95.5%, respectively) were statistically lower than those from undamaged plots. These results were inconsistent with those observed in identical work in 2002 when bolls from only the 50 and 100% levels of injury had significantly reduced yields (Greene and Capps, 2003b). Yields from bolls injured at the 10, 20, and 30% level were not significantly reduced in 2002. This suggested that other factors (e.g., weather, variety, etc.) complicated

the study, preventing repetition of the results from year to year. However, these data do support results from the current boll-injury threshold research where protection at the lowest level (10%) provided the highest yields and returns. It remains our opinion that the most appropriate threshold for stink bug management in cotton is between 10 and 30% when sampling medium-sized bolls and using the damage criterion of at least one internal feeding injury per boll described previously (Greene et al., 1999, 2001a), understanding that populations of other boll feeders such as TPB can contribute significantly to boll injury and must be managed properly.

Yields were not significantly reduced when terminal growth was mechanically removed by hand at 25, 50, and 100% (Table 2). Plant height was significantly reduced at the 100% level. Yields were significantly reduced when pre-floral buds were mechanically removed by hand at 100% for the first four weeks of squaring (Table 3). These and previous results (Greene and Capps, 2003b) demonstrate that excessive terminal and square losses from insects, specifically the bug complex (stink bugs or plant bugs), in early-squaring cotton can result in significant loss of canopy structure and yield. It is widely known that plant bugs can and will injure squares and terminal growth, but observational work has questioned whether or not stink bugs are capable of injuring meristematic tissue and pre-floral buds as well. Although stink bugs are primarily fruit/seed feeders, their potential capacity, along with related species of plant bugs, to injure terminal growth and squares should caution growers when elevated populations are encountered in young cotton.

PRACTICAL APPLICATION

Results from these studies addressing simulated mechanical injury to bolls, terminals, and squares suggested that losses from bug feeding injury to young cotton and to small- to -medium-sized bolls could be significant under certain circumstances.

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Table 1. Average yield from simulated mechanical injury to cotton bolls with insect pins at intended treatments.

Treatment (actual %)	Yield (lb/A)
UTC	1053a[1]
10% punctured (11.6%)[2]	852b
20% punctured (22.2%)	840b
30% punctured (32.5%)	879b
50% punctured (48.8%)	866b
100% punctured (95.5%)	708c

[1]Actual percentage injury.
[2] Means followed by the same letter are not significantly different (P=0.05).

Table 2. Average yield and plant height from simulated terminal injury to young cotton by hand removal of terminal growth.

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Treatment	Plant height (in)	Yield (lb/A)
UTC	35.80a	1748a[1]
25% removed	34.38a	1711a
50% removed	33.40ab	1567a
100% removed	31.75b	1659a

[1]Means followed by the same letter are not significantly different (P=0.05).

Table 3. Average yield from simulated pre-floral bud injury to young cotton by hand removal of squares.

Treatment	Yield (lb/ A)
UTC	1726a[1]
25% removed (4 wk)	1604a
50% removed (4 wk)	1658a
100% removed (4wk)	1352b

[1]Means followed by the same letter are not significantly different (P=0.05).

CONTROL OPTIONS FOR THRIPS IN SOUTHEAST ARKANSAS 2003

C.D. Capps, J. K. Greene, G.M. Lorenz, P.R. Smith, D.R. Johnson, and G. Studebaker[1]

RESEARCH PROBLEM

In-furrow treatments such as aldicarb (Temik) continue to be standards for thrips control in southeast Arkansas. The widespread use of Temik is due to its effectiveness in suppressing nematodes as well as thrips populations. Seed treatments, such as thiamethoxam (Cruiser), imidacloprid (Gaucho), and acephate (Orthene), along with foliar materials, offer valuable options for thrips control. Some treatments may be used in combination to offer the most effective control of thrips. Research must continue to evaluate control offered by new and existing compounds.

BACKGROUND INFORMATION

Thrips continue to be perennial early-season pests of cotton in southeast Arkansas. Thrips begin to move into cotton from wild hosts and wheat as they senesce and can reach high enough populations to cause economic damage to cotton if left untreated (Herbert 1995, Roberts and Rechel, 1996). Heavy infestations of thrips can cause abortion of the terminal resulting in branching and excessive vegetative growth, which can lead to delayed maturity and reduced yields (Micinski et al., 1990). Seed treatments along with in-furrow treatments continue to be valuable options for early-season thrips control (Greene et al., 2003, Johnson et al., 2003). Foliar sprays alone can also provide effective but variable control of thrips.

[1] Pest management technical support specialist, extension entomologist, Southeast Research and Extension Center, Monticello; extension entomologist, Cooperative Extension Service, Little Rock; extension program technician, Cooperative Extension Service, pest management section leader , Little Rock; and extension entomologist, Northeast Research and Extension Center, Keiser, respectively.

RESEARCH DESCRIPTION

Cotton (*Gossypium hirsutum* L.) Stoneville 4892 B/R was planted on 30 April 2003 at the Southeast Branch Experiment Station near Rohwer, Arkansas (Tests I and II). Plots measured 8 rows by 40 feet, spaced 38 inches apart, with four replications of each treatment arranged in a randomized complete block design. Standard fertilization and herbicide practices were followed according to current University of Arkansas Extension recommendations (Chapman, 2000). For Test I and II, thrips were collected on 13, 16, 20, 23, 27, and 30 May and on 2 June by randomly pulling 10 plants from rows 2 and 7 of each plot and washing them in 1-quart jars of 70% isopropyl alcohol. Nymphs and adults were counted following filtration procedures in the laboratory. In Test III, cotton (Suregrow 215 BG/RR) was planted on 13 May 2003 at the Southeast Branch Experiment Station near Rohwer, Arkansas. Plot size, agronomic practices, and sampling procedures were identical to those used in Tests I and II. Sampling dates were 30 May and 2, 5, 9, 16, and 19 June 2003. Data were processed using Agriculture Research Manager (Gylling Data Management, Inc., Brookings, S.D.), and means were separated using Least Significant Difference (LSD) procedures following significant F tests using Analysis of Variance.

RESULTS AND DISCUSSION

Test I

All treatments provided significant control of thrips up to 27 days after planting (27 DAP) (Table 1), duplicating results seen in other trials (Lentz et al., 2003, Greene et al., 2003). At 30 DAP, numbers of thrips in Gaucho and Cruiser seed treatments (ST) did not significantly differ from those in the untreated control (UTC), but did at 33 DAP. All treatments yielded significantly higher than the UTC, with Cruiser yielding the most numerically, as observed in previous trials (Greene et al., 2003).

Test II

All treatments, except foliar-applied Dimethoate (pre-treatment at 13 DAP), provided significant control of thrips populations across all sample dates when compared with the UTC (Table 2). Dimethoate plots had the lowest numbers of thrips numerically across most dates due to three foliar treatments applied during the trial. Only Cruiser yielded significantly more than the UTC.

Test III

All treatments provided significant control of thrips across the first three post-treatment sample dates when compared with the UTC (Table 3). At 4DAT3, Dimethoate (0.25 lb ai/a) and Bidrin (0.20 lb ai/a) did not significantly differ from

the UTC, and Bidrin (0.20 lb ai/a) was not significantly different from the UTC at 7DAT3.

PRACTICAL APPLICATION

Seed treatments such as thiamethoxam (Cruiser) and imidacloprid (Gaucho) provided control equal to or better than aldicarb (Temik). Yields in plots treated with Cruiser were highest. However, our plots at the Southeast Branch Experiment Station were located in areas without significant populations of nematodes, de-emphasizing potential suppression of damaging densities of nematodes with aldicarb. Because Temik provides suppression of nematodes in infested areas and controls thrips as well as, product choice (seed treatment or in-furrow) should depend on the presence or absence of nematodes at threshold levels. Foliar sprays, compared without seed treatments or in-furrow products, were effective in controlling thrips and produced more cotton when compared with the UTC. However, in most years, cotton seedlings undergo significant feeding pressure from thrips that is not economically remedied with repetitive applications of foliar insecticides, justifying annual applications of preventative measures such as in-furrow or seed treatment insecticides.

ACKNOWLEDGMENTS

We thank the staff at the Southeast Branch Experiment Station, Rohwer Branch, for their assistance. We also thank our workers Joe Belvedresi, Michael Dodson, Brian Lawhon, Heather Jaggers, Greg O'Neal, Keith Sowell, Michael Shepard, Cory Bryant, Randy Dixon, and Jeremy Spurlock for their assistance in helping conduct our research.

DISCLAIMER

The mention of trade names in this report is for informational purposes only and does not imply an endorsement by the University of Arkansas Cooperative Extension Service.

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Table 1. Average number of adult and immature thrips per 10 plants (Test 1).

Treatment/Rate	13 May 13DAP	16May 16DAP	20May 20DAP	23May 23DAP	27May 27DAP	30May 30DAP	2June 33DAP	Yield Lint
UTC	27.5a[1]	78.5a	725.a	233.3a	264.3a	159.0a	242.0a	1098.3b
Temik 3.5lb	4.0b	12.3c	25.8b	26.0b	53.3b	63.3c	82.8c	1300.6a
Temik4.0lb	5.5b	8.0c	24.5b	30.5b	54.3b	51.3c	75.0c	1393.9a
Temik5.0lb	2.8b	7.3c	18.8b	19.0b	40.0b	74.3bc	73.8c	1385.6a
Cruiser ST	1.5b	9.8c	16.8b	21.5b	37.3b	117.5ab	99.8bc	1397.7a
GauchoST	5.5b	23.8b	26.0b	34.3b	56.0b	128.8a	132.5b	1334.5a

[1] Means followed by same letter do not significantly differ (*P*=0.05, LSD).

Table 2. Average number of adult and immature thrips per 10 plants (Test II).

Treatment/ Rate	13 May 13 DAP	16 May 16 DAP	20 May 20 DAP	23 May 23 DAP	27 May 27 DAP	30 May 30 DAP	2 June 33 DAP	Yield @ 35% Lint
UTC	28.0 a	59.8 a	92.0 a	281.8 a	303.0 a	277.5 a	265.5 a	1294.6 bc
Temik 3.5 lb	2.3 b	14.5 b	33.3 b	33.8 b	45.0 bc	99.0 bc	112.5 b	1381.6 ab
Temik 3.5 lb	2.5 b	9.8 bc	29.3 bc	32.3 b	48.5 bc	107.3 bc	112.5 b	1287.1 bc
Temik 5.0 lb	3.8 b	9.0 bc	26.5 bc	26.3 b	47.0 bc	84.8 bc	109.0 b	1166.0d
Temik 5.0 lb	1.3 b	2.3 c	22.8 bc	24.5 b	29.0 bc	64.5 bc	105.5 bc	1361.6 ab
Temik 5.0 lb Gaucho ST	2.3 b	4.8 bc	11.0 bc	14.0 b	25.3 bc	55.3 bc	46.3 cd	1385.6 b
GAucho ST	7.3 b	15.5 b	19.5 bc	51.0 b	82.8 b	152.8 b	136.0 b	1208.8 cd
Cruiser ST	2.3 b	10.8 bc	14.0 bc	30.0 b	55.5 bc	135.3 b	109.8 b	1472.1 a
Dimethoate 0.25 lb/ai/a	26.0 a	2.0 c	15.8 bc	12.3 b	6.0 c	3.5 d	14.0 d	1370.6 ab

[1] Means followed by same letter do not significantly differ (*P*=0.05, LSD).

Table 3. Average number of adult and immature thrips per 10 plants (Test III).

Treatment /Rate lb ai/a	30 May Pretreat	2 June 3DAT1	5 June 6DAT1	9 June 4DAT2	16June 4DAT3	19June 7DAT3
UTC	35.8a1	65.0a	78.0a	40.0a	26.0ab	27.3a
Dimethoate 0.25	27.3a	23.8b	18.8b	8.3b	16.5ab	4.3b
Orthene 0.25	23.3a	13.5b	22.8b	4.5b	10.8b	2.3b
Bidrin 0.25	26.3a	27.0b	12.3b	9.0b	8.8b	1.0b
Mointor 0.25	31.5a	16.5b	23.3b	8.0b	10.5b	3.0b
Bidrin0.20	26.5a	19.0b	25.3b	12.3b	38.0a	18.8a

[1] Means followed by same letter do not significantly differ (*P*=0.05, LSD).

EFFECT OF BOLL AGE ON STINK BUG FEEDING AND YIELD LOSS

J.K. Greene and C.D. Capps[1]

RESEARCH PROBLEM

Stink bugs will continue to be a part of the boll-feeding bug complex that injures cotton during mid -to-late season. Effective insecticides are still available for their control, along with adequate recommendations for when to initiate and continue treatment. Information concerning when to cease insecticide treatments for stink bugs in cotton is still limited and needs attention.

BACKGROUND INFORMATION

Stink bugs continue to be problem pests in cotton because of limited broad-spectrum insecticide use for traditional major pests. Widespread adoption of transgenic *Bt* cotton and impending use of second-generation *Bt* cultivars, enhanced in controlling worm pests, along with eradication of the boll weevil, *Anthonomus grandis* Boheman, and availability of selective, target-specific insecticides (primarily for control of worm [*Lepidoptera]* pests), have all brought about significant reductions in broad-spectrum foliar insecticide usage, and stink bugs have escaped coincidental control. The stink bug problem in cotton has received much attention in recent years and information concerning management of stink bugs in cotton is becoming more available (Greene et al., 1999; Greene et al., 2001a, b; Willrich et al., 2002, 2003; Greene and Capps, 2002, 2003).

Predominant phytophagous (plant-feeding) stink bugs in the Southeast and much of the Mid-South are similar and include the green stink bug (GSB), *Acrosternum hilare* (Say), the southern green stink bug.

RESEARCH DESCRIPTION

Adults and late instars of GSB were collected from soybeans with sweep net procedures and held until used in the experiments using procedures described previously. On 18 July 2003, insect cages (either 6 x 6 x 12 ft or 6 x 6 x 6 ft), constructed using 18 x 14 mesh screen and aluminum pipe frames, were placed over second-generation *Bt* cotton (*Gossypium hirsutum* L.) cultivar DP468 BIIRR

[1]Extension entomologist and pest management technical support specialist, respectively, Southeast Research Extension Center, Monticello.

(SGSB), *Nezara viridula* (L.), and the brown stink bug (BSB), *Euschistus servus* (Say). Several other species are part of the plant-feeding stink bug complex, but are of less importance. In 2003, we investigated the ability of GSB to injure bolls of varying ages in cage experiments designed to define the duration of susceptibility to bug injury, planted on 5 May near the Southeast Research and Extension Center in Monticello, Arkansas. On 24 July and 5 August, esfenvalerate (Asana XL 0.66EC at 0.05 lb ai/a), dicrotophos (Bidrin 8EC at 0.5 lb ai/a), and spinosad (Tracer 4 at 0.09 lb ai/a) were applied to caged plants, using a compressed-air backpack sprayer that delivered 10 gal/a at 50 psi, to kill arthropods present. White blooms on enclosed cotton were tagged with fluorescent flagging tape every 2 or 3 days (d) and dated. Small cages, designed to enclose a single boll, were constructed of 12 oz polystyrene foam cups, knee-high nylon hose, rubber bands, and wire ties (Greene et al., 1999). Bottoms of cups and toe-ends of nylon hose were removed, and cups were placed in the middle of the hose sleeves. The bottom end of a cup cage was placed over a boll to enclose it, and the sleeve was tied with a wire tie to the peduncle of the boll. An experiment was initiated by placing a single stink bug inside a cup with the boll, folding the other end of the sleeve over the top of the cup and securing it with a rubber band. Dead bugs were removed from cages and replaced daily.

The effect of boll age on stink bug feeding and yield loss was addressed by confining adults and late 5th instars of *A. hilare* singly with bolls aged 4, 8, 14, 18, 21, 27, and 32 days from white bloom using a completely randomized design. Paired bolls of corresponding age were caged without bugs as controls. After a 7-d exposure, bugs were removed from the cages. At maturity, cotton was manually harvested and weighed from each boll. Data were processed using SAS software, and means were separated using Least Significant Difference procedures following significant F tests using Analysis of Variance.

RESULTS AND DISCUSSION

As bolls aged, damage and yield loss decreased (Fig. 1). Significant yield loss did not occur with bolls aged 27 or 32 d from anthesis that had accumulated over 583 heat units (HU). In our earlier findings using a related species, the southern green stink bug, *Nezara viridula* (L.), results were almost identical where bolls aged 25 and 30 d that had accumulated 559 and 658 HU, respectively, did not incur yield loss (Greene et al., 2001a). In earlier tests with *N. viridula* (Greene and Herzog, 2000), bolls aged 21 d with over 405 HU accumulated did not suffer significant yield reduction. These results were similar to even earlier findings where bolls aged 18 d with over 380 HU did not display significant symptoms of feeding damage from SGSB (Greene et al., 1999). Results were obtained from cotton under field cages that provided ca. 18% shade to enclosed plants and with field-collected/laboratory-held stink bugs confined to single bolls for an entire week. Considering the effects of shading and extended length of exposure to bug injury, bolls are likely safe from significant yield loss due to stink bugs when they attain an age of 21-25 d from anthesis (ca. 3 wk old) and/or an

accumulation of 450-550 HU. Because bolls would likely increase in size and mature faster with full canopy exposure to solar radiation and because of the artificially intimate and intense exposure to stink bugs in the enclosures, this should be a conservative estimate. Because bolls become resistant to bug feeding and damage as they age, we should be better able to decide when to terminate insecticide use for stink bugs based on these results.

PRACTICAL APPLICATION

The ability of GSB to damage cotton bolls and reduce yield decreased as bolls aged, and yields from bolls that accumulated 583 HU at 27 d following anthesis were not significantly reduced. This estimate of a point at which cotton bolls are "safe" from significant yield loss due to stink bug injury is conservative. These results are similar to those found recently with BSB and SGSB and provide information concerning termination rules for insecticide applications late in the season for stink bugs.

ACKNOWLEDGMENTS

We thank Cotton Incorporated and Arkansas cotton producers for support of this work. We also thank our workers Joe Belvedresi, Michael Dodson, Brian Lawhon, Heather Jaggers, Greg O'Neal, Keith Sowell, Michael Shepard, Cory Bryant, Randy Dixon, and Jeremy Spurlock for their assistance in helping conduct our research.

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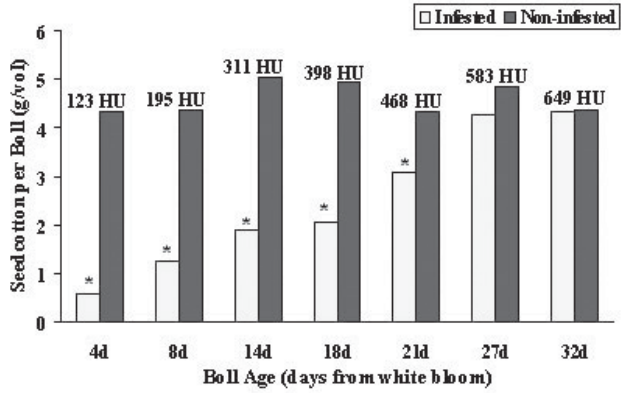

Fig. 1. Seedcotton yields following one week exposure of bolls of varying ages to adults and late 5th instars of green stink bug, *Acrosternum hilare* (Say), from DP468BIIRR cotton in 2003. *Significant difference P≤0.05. HU = heat units (calculated by averaging daily temperature °F- 60 for each day).

AN ECONOMIC COMPARISON OF TRANSGENIC AND NON-TRANSGENIC COTTON PRODUCTION SYSTEMS IN ARKANSAS

K. Bryant, J.K. Greene, C.D. Capps, F.E. Groves, C. Tingle, G.Studebaker, F.M. Bourland, B. Nichols, and J. Reeves [1]

RESEARCH PROBLEM

Transgenic cultivars have been widely accepted by producers. Transgenic cotton cultivars provide growers with additional management options for weed and insect control. Although these cultivars are widely adopted among growers, they have undergone only limited available research that evaluates their overall agronomic and economic performance (Bourland et al., 1997). There is a current need for systems-level research evaluating how these cultivars will perform under a wide variety of pest complexes and cultural methods and to compare their costs, and gross, and net returns to the grower.

BACKGROUND INFORMATION

In 2002, the USDA-AMS Cotton Division reported that approximately 94% of the cotton acreage in Arkansas was planted to transgenic cultivars (USDA-AMS, 2002). More specifically, 3% was planted to *Bt*, *Bacillus thuringiensis* (*Bt*), 7% was planted to BXN,27% was planted to Roundup Ready, and 55% was planted to *Bt* + Roundup Ready cultivars. Growers now have the option to plant Bollgard cultivars that express an organic toxin synthesized by the bacterium. *Bt* cultivars express the toxin in the foliage, bracts, and carpels. When certain lepidopteran pests, notably the heliothine insects, tobacco budworm *(Heliothis, virescens*) and cotton bollworm (*Helicoverpa zea*), feed on Bollgard cotton, the *Bt* toxin paralyzes the mid-gut of susceptible insects and they die as small caterpillars (Benedict, 1996). Other transgenic cultivars have been developed that have the ability to withstand non-selective herbicides such as glyphosate (Roundup Ready) or bromoxynil (BXN) (Collins, 1996; Stewart, 1996).

[1] Area extension specialist-farm management, extension entomologist, pest management technical support, Southeast Research and Extension Center, Monticello; research specialist, Southeast Research and Extension Center, Rhower; agronomist, entomologist, director, Northeast Research and Extension Center, Keiser; project director, and associate director, Cotton Incorporated, Cary, North Carolina, respectively.

Newer cultivars have

Newer cultivars have incorporated both the herbicide resistance and *Bt* expressions in order to provide both insect and weed management capabilities. Early research evaluating *Bt* cotton primarily had an entomological focus. A similar narrow focus on weed control and cotton tolerance was also observed with the BXN and Roundup Ready cultivars.

RESEARCH DESCRIPTION

Field studies were initiated in 2001, 2002, and 2003 at the Northeast Research and Extension Center (NEREC) at Keiser, Arkansas, and the Southeast Branch Experiment Station (SEBES) at Rohwer, Arkansas. Cotton was planted on May 15, 2001, May 31, 2002;,and May 28, 2003 at NEREC; and on June 7, 2001, May 21, 2002, and May 12, 2003, at SEBES. Plot size was four rows 0.9 m by 15 m long. The experimental design was a randomized complete block with four replications. The plots at the NEREC were managed under a no-till system. The plots at the SEBES were managed using a more conventional system of spring tillage and mechanical cultivations when appropriate.

Roundup Ready, BXN, Bollgard, and Roundup Ready plus Bollgard cultivars were chosen based on their performance in the University of Arkansas Official Variety Tests (Benson et al., 2001) and percentage of acreage planted in Arkansas (UDSA-AMS, 2001). The cultivars included in the study by year are listed in (Table 1).

All plots were managed to maximize yields according to University of Arkansas Cooperative Extension Service recommendations. Herbicide systems were chosen based on the genetic capabilities for each cultivar. For example, Roundup UltraMax® was the primary herbicide for Roundup Ready and Roundup Ready plus Bollgard cultivars, Buctril herbicide was used for BXN 47®, and cotton-selective herbicides were used with non-transgenic cultivars. After emergence, plots were scouted for insects weekly. As with the herbicide systems, insecticide applications were based on the genetic capabilities of each cotton cultivar. At both locations, the two center rows of each plot were machine-harvested.

Plot yields were multiplied by the base Arkansas Commodity Credit Corporation loan rate to arrive at gross returns for each treatment. The base loan rate was $0.5230/lb in 2001, $0.524/lb in 2002, and $0.5235/lb in 2003. Treatment costs including seed, technology fees, herbicide, insecticide, and application costs were determined for each cultivar. These expenses were subtracted from gross returns to calculate the returns-over-treatment-cost per cultivar.

RESULTS AND DISCUSSION

Yields

In 2001, no significant differences were observed in yield at the NEREC, while at the SEBES, the cultivars ‘SG 215 BR’, ‘ST 4892 BR’, and ‘DPL 20 BG’

produced higher yields than did several of the others (data not shown).

In 2002, Paymaster '1199 RR' was numerically the highest yielding cultivar at both locations. However, at the NEREC, 'PM 1218 BR', SG 215 BR and DPL20 BG produced as much lint as did Paymaster 1199 RR, and at SEBES, seven other cultivars produced yields that did not significantly differ from those of Paymaster 1199 RR. Stoneville BXN 47 yielded at or near the bottom at both locations. Three of the top four yielding cultivars at NEREC contained the Roundup Ready gene. Two of the three lowest yielding cultivars at SEBES contained the Roundup Ready gene.

In 2003, Phytogen 355 was the numerically highest yielding cultivar at NEREC, with four other cultivars not significantly different in yield. Stoneville 5599BR was the numerically highest-yielding cultivar at SEBES and Phytogen 355 was not significantly different in yield.

Pest Management Costs, Gross, and Net Returns

The economic analysis showed a tendency for the highest yielding cultivars to produce the greatest returns. However, in some instances, the yields and returns were very close, and in such instances the costs affect the ranking of net returns among some of the varieties. At NEREC, the Roundup Ready system was least expensive in all three years (Table 2). At SEBES, the Roundup Ready system was the cheapest in 2001 and 2003, while the system using non-transgenic cultivars and cotton-selective herbicides was the least costly in 2002 (Table 3).

The Bollgard system was not the least costly system of insect management at either location in any year. Savings on insecticides and application were not sufficient to offset the increased cost of technology and seed. However, some cultivars containing the Bollgard gene were advantageous in some years because of their high yields. Differences in herbicide and insecticide costs from year to year are an indication of the variability in weed and insect pressure across years.

PRACTICAL APPLICATION

Eight of the cultivars were grown in all three years. The annual returns-over-treatment-costs and the three-year average for these cultivars are displayed in (Tables 2 and 3). It is clear that no one cultivar had the greatest return each year and differences between cultivars do exist within years. However, over the long run, as expressed by the three-year averages, differences between some cultivars were relatively small. No single cultivar or type of production system stands out as always resulting in the greatest return. Choosing the cultivar with the greatest return in a given year ex-ante would be difficult. Most likely a mix of cultivars would provide the producer with an acceptable average return and a reduction in variability.

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Table 1. Cotton cultivars serving as treatments and year of their inclusion.

Stoneville ST 474[123]	FiberMax FM 966[123]	Paymaster PM 1218 BR[2]
Stoneville St 4793 R [123]	PhytoGen PSC355[123]	Suregrow 521 R[3]
Stoneville ST 4892 BR[123]	Suregrow SG 215 BR[123]	Fibermax 958 B[3]
Stoneville ST 4691 B [123]	Paymaster PM 1199 R[12]	Stoneville 5599 BR[3]
Stoneville BXN 47 [123]	Deltapine 20 B[12]	

[1] Planted in '01.
[2] Planted in '02.
[3] Planted in '03.

Table 2. Returns[1] for each cultivars across years, Northeast Research and Extension Center (NEREC).

Cultivar	2001	2002	2003	Avg.
PSC 355	437.63	324.68	228.05	330.12
SG 215BR	480.21	350.70	143.13	324.68
ST 4793R	432.34	328.26	182.09	314.23
ST BXN 47	451.78	285.74	153.04	296.85
ST 4691B	386.93	313.35	175.77	292.02
ST 4892BR	394.18	311.15	16802	291.12
FM 966	442.31	291.64	132.22	288.72
ST 474	387.89	241.31	164.14	264.45

[1] Returns above cultivar, weed, and insect management costs.

Table 3. Returns[1] for each cultivars across years, Southeast Arkansas (SEBES).

Cultivar	2001	2002	2003	Avg.
ST 4892 BR	330.48	868.53	551.74	583.58
ST 474	244.97	933.76	558.82	579.18
PSC 355	219.82	921.14	572.38	571.11
ST 4691B	203.25	916.12	535.36	551.58
FM 966	262.73	849.90	519.01	543.88
SG 215BR	361.49	740.30	516.29	539.36
ST 4793R	256.71	768.37	471.11	498.73
ST BXN47	238.37	740.12	494.19	490.89

[1] Returns above cultivar, weed, and insect management costs.

Bt COTTON PERFORMANCE IN ARKANSAS IN 2003: AN ECONOMIC EVALUATION

K. Bryant, J.K. Greene, G..M. Lorenz, B. Robertson, and G. Studebaker[1]

RESEARCH PROBLEM

The number of transgenic cotton cultivars available for commercial production has increased greatly in recent years. Cotton producers now have multiple choices when choosing transgenic cotton cultivars. The choice of cultivar now dictates the insect and weed control programs that will or can be used. It is estimated that, in 2003, at least 77% of Arkansas' cotton acreage was planted to a stacked-gene cultivar while an additional 11% was planted to a single-gene Roundup Ready cultivar (Anonymous, 2003). An economic evaluation of insect control methods provides valuable information to producers and researchers.

BACKGROUND INFORMATION

The University of Arkansas, in cooperation with Arkansas cotton producers, county agents and industry representatives, has implemented side-by-side comparisons of Bollgard cotton cultivars to non-*Bt* cultivars each year beginning in 1996 (Bryant et al., 2002). In 2003, stacked-gene cultivars were compared to Roundup Ready cultivars in some cases and to conventional cultivars in other cases. This article presents the economic results of those comparisons.

RESEARCH DESCRIPTION

Four cotton growers in southeast Arkansas and two in northeast Arkansas agreed to cooperate in these comparisons. In all areas, fields were chosen that were very similar in nature. Each field was managed using Best Management Practices for that field and cultivar. The primary differences in management between the two fields being compared in each observation involved insect control due to the presence or absence of the *Bt* gene. In cases where the stacked-gene cultivar was compared to a conventional cultivar, herbicide programs also differed. However, differences in herbicide applications were ignored in this analysis. To

[1] Area extension specialist, extension entomologist, Southeast Research and Extension Center, Monticello; extension entomologist, cotton extension agronomist, Cooperative Extension Service, Little Rock; and entomologist, Northeast Research and Extension Center, Keiser, respectively.

make the economic comparison fairer in these cases, the technology fee assigned to the stacked gene cultivar was reduced by the amount attributable to the Roundup Ready technology. In short, a Bollgard-alone technology fee was assigned to the stacked gene cultivar instead of a stacked -gene technology fee.

Partial budgeting was used to quantify the change in profit associated with growing the stacked-gene cultivar rather than the single gene or conventional cultivar. In each comparison, changes in revenue and variable costs were determined. Most of the input prices for insecticides, applications, seed, and technology fee were obtained from the 2003 cotton production cost estimates published by the University of Arkansas (Bryant and Windham, 2002). Input prices that were not available in these publications were obtained by surveying local distributors. Cotton lint was valued at $0.57 per pound. This represents the ten-year average cotton price received by Arkansas farmers from 1993 to 2002 (Arkansas Agricultural Statistics Service, 2003).

RESULTS AND DISCUSSION

Partial budgeting results for seventeen comparisons in southeast Arkansas are displayed in (Table 1). The “change in gross return” column lists the changes in gross returns associated with growing the *Bt* cultivar instead of the non-*Bt* cultivar. This change in returns is the result of the yield difference between the two cultivars. Growing the *Bt* cultivar increased gross returns in six of the seventeen observations. The average change in gross return for the seventeen observations was negative $45.20 per acre.

The “change in variable cost” column lists the increase or decrease in variable cost associated with growing the *Bt* cultivar instead of the non-*Bt* cultivar. These changes are the result of differences in seed costs, technology fees, and insecticide programs. Of the seventeen observations, growing the *Bt* cultivar reduced the variable cost on four occasions. On average, variable cost increased $11.60 per acre when growing the *Bt* cultivars.

The “change in profit” column lists the increase or decrease in profit associated with growing the *Bt* cultivar. These changes in profit are the result of the changes in gross returns and the changes in variable costs. Profit increased in five of the seventeen observations. On average, profit decreased $56.80 per acre.

Partial budgeting results for five comparisons in northeast Arkansas are displayed in (Table 2). Growing the stacked-gene cultivar caused a reduction in gross returns for all five observations. On average, gross returns decreased by $40.93 per acre.

Of the five observations, growing the stacked-gene cultivar did not reduce variable costs on any occasion. On average variable cost increased $24.49 per acre when growing the stacked-gene cultivar.

Change in profit was negative for all five observations. On average, profit decreased $65.42 per acre.

PRACTICAL APPLICATION

Bollgard cotton is often grown as a risk management tool. In these observations, the advantage was to the non-*Bt* cultivars.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the contributions of Steve Stevens, Johnny McGraw, Greg Simpson, James Ruggeri, and two anonymous farmers for providing the field records for this analysis. We also thank Chuck Capps and Jessica Trauger for their assistance in compiling the information and preparing the poster.

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Table 1. Cultivar change in gross returns, change in variable cost, and change in profit for comparison of *Bt* cultivars and non-*Bt* cultivars: Southeast Ark.

Cultivars	Change in gross returns	Change in variable cost	Change in profit
	----------	----------	----------
ST 5599 BG/RR FM 966	131.67	(21.72)[1]	153.39
DPL 451 B/RFM 966	60.99	14.15	46.84
ST 4892 BG/RR Fm 958	19.38	(17.64)	37.02
ST 4892 BG/RR FM 958	42.75	25.98	16.77
DPL 451 B/R FM 968	39.90	32.59	7.31
DPL 451 B/R DP 436 RR	14.25	25.20	(10.95)
ST 5599 BG/RR FM 966	0.00	18.37	(18.37)
DP 451 B/R/ DP 436 RR	(13.68)	9.31	(22.99)
FM 960 B/R FM 958	(13.68)	25.64	(39.32)
ST 4892 BG/RR FM 966	(61.56)	(2.01)	(59.55)
DPL 451 B/R FM 966	(57.00)	9.04	(66.04)
ST 4892 BG/RR FM 966	(55.29)	35.29	(90.58)
DPL 451 B/R FM 958	(97.47)	13.02	(110.49)
DP 451 B/R PSC 355	(121.98)	12.36	(134.34)
ST 4892 BG/RR FM 958	(178.41)	4.51	(182.92)
DPL 451 B/R FM 958	(224.01)	15.39	(239.40)
DPL 451 B/R FM 958	(254.22)	(2.30)	(251.92)
AVERAGE	($45.20)	$11.60	($56.80)

[1] Parentheses indicate a negative value.

Table 2. Cultivar change in gross returns, changes in variable cost, and change in profit for comparison of stacked-gene cultivars and single -gene cultivars: Northeast Ark.

Cultivars	Change in gross returns	Change in variable cost	Change in profit
PM 1218 BG/RR SG 521 RR	(3.99)[1]	27.20	(31.19)
SG 215 BG/RR SG 521 RR	(6.27)	27.37	(33.64)
PM 1218 BG/RR DPL 436 RR	(25.65)	12.94	(38.59)
PM 1218 BG/RR FM 966	(44.46)	27.58	(72.04)
PM 1218 BG/RR SG 521 RR	(124.26)	27.37	(151.63)
AVERAGE	(40.93)	24.49	65.42

[1] Parentheses indicate a negative value.

ECONOMIC EVALUATION OF EARLY-SEASON INSECT CONTROL IN COTTON

K. J. Bryant, G. L. Lentz, and N. B. Van Tol, [1]

RESEARCH PROBLEM

Early-season insect control is one of the first choices a producer must make in order to protect a young crop. The standard treatment, to which most others have been compared, is an at-planting treatment of aldicarb granules (Temik). Gaucho (imidacloprid) is another popular crop protection treatment. Other important in-furrow treatments are disulfoton (Di-Syston), acephate (Orthene), and imidacloprid (Admire). An economic analysis comparing treatments will help producers in making informed decisions about early-season insect control.

BACKGROUND INFORMATION

Lack of early- season protection for a cotton crop can result in a complete loss of stand, necessitating replanting, or under less severe situations, significant damage, which leads to loss of vegetative branching and delays in crop fruiting and developments. A delay in fruiting and development makes the crop more susceptible to late-season pests such as loopers, armyworms, and boll feeders. Management of early-season thrips may be accomplished by at-planting treatments of in-furrow granules or sprays, seed treatments, or post planting foliar sprays. Foliar sprays have been primarily used as salvage treatments when at-planting treatments have failed or pest populations have reached outbreak proportions.

RESEARCH DESCRIPTION

This study examined the expected change in profit associated with using Gaucho instead of Temik. Field experiments were conducted from 1994 to 2001 at two locations in west Tennessee. All of these experiments included Temik and Gaucho comparisons. Some included other treatments as well. The Temik plots received 0.5 lbs of aldicarb per acre while the Gaucho plots received 0.25 lb of imidacloprid per hundred-weight of seed. Experiments were established in a randomized complete block design and replicated five times. All plots were non-

[1] Area extension specialist-farm management, Southeast Research and Extension Center, Monticello; associate professor, Entomology and Plant Pathology, Jackson Tennessee; and research associate, West Tennessee Experiment Station, Jackson, Tennessee, respectively.

irrigated and had no history of nematode infestation. Seeding rates were approximately twelve pounds of seed per acre.

First harvest and total harvest yields were collected. Means were calculated for each treatment at each location and separated using the SAS GLM LSD procedure. Treatment costs were calculated using current price information supplied by local distributors. These prices averaged $3.28/lb of material for Temik and $9.96/oz of material for Gaucho.

RESULTS AND DISCUSSION

Mean cotton lint yields across all years at each location are displayed in Figures 1 through 4. Both treatments affected a statistically significant yield increase over the untreated check. Numerically, the Temik treatments had higher yields at both locations and at both harvests. However, the yield differences are small (Gaucho yields are approximately 3% less than the Temik yields) and are not significantly different at the alpha = 0.05 level. Costs for the two treatments were very similar. At eight ounces of product per 100 pounds of seed, and assuming a 12 lb/acre seeding rate, the Gaucho treatment cost $9.55 per acre for the material plus the cost of treating the seed. The Temik treatment cost $10.92 per acre for the material plus the time and machinery to apply an in-furrow insecticide.

PRACTICAL APPLICATION

No measurable difference in profit was found between the two treatments. Average yields between the treatments were not statistically different, and the cost difference between the two treatments was negligible. Based on these observations, either treatment is economical for early-season insect control. Using a seed treatment like Gaucho, instead of an in-furrow treatment like Temik, does have a convenience factor that was not considered in this study. This convenience might also translate into timelier planting on large acreages.

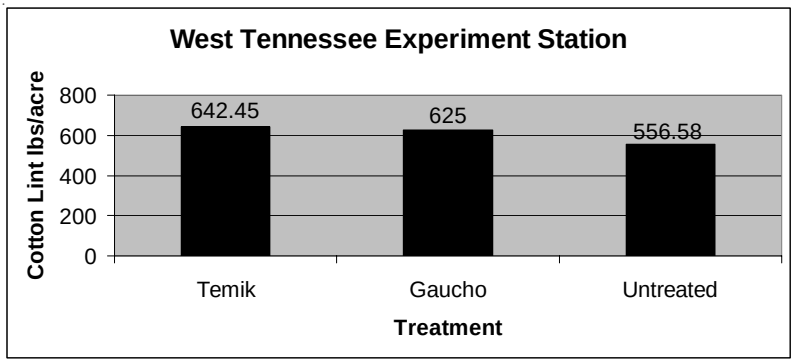

Fig. 1. Average first harvest yield by treatment across years: 1995, 1996, 1997, 1998, and 2000.

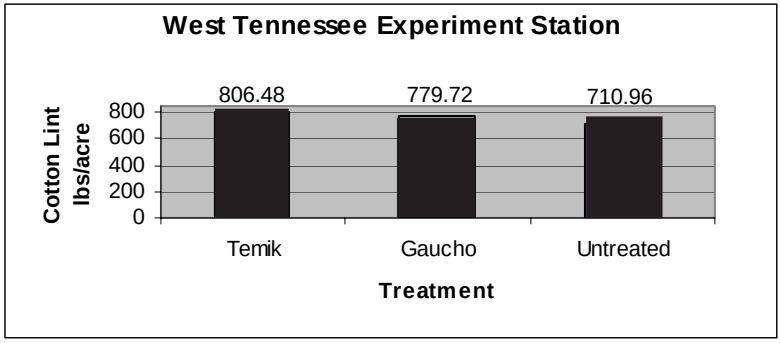

Fig. 2. Average total harvest yield by treatment across years: 1995, 1996, 1997, 1998, and 2000.

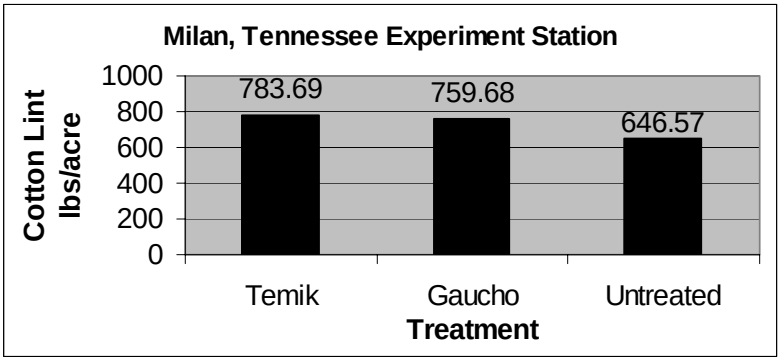

Fig. 3. Average first harvest yield by treatment across years: 1995, 1996, 1997,1998, 1999, 2000, and 2001.

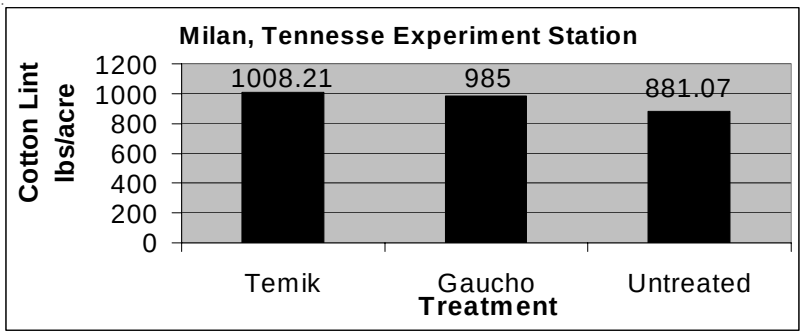

Fig. 4. Average total harvest yield by treatment across years: 1995, 1996, 1997, 1998, 1999, 2000, and 2001.

RISK-RETURNS OF COTTON AND SOYBEAN ENTERPRISES FOR MISSISSIPPI COUNTY, ARK.: A COMPARISON OF ALTERNATIVE MARKETING STRATEGIES WITHIN A WHOLE FARM FRAMEWORK

G. Rodríguez, A. McKenzie, and L. Parsch[1]

RESEARCH PROBLEM

In the state of Arkansas, crop production represents an important agricultural sector of the economy. However, crop farmers have to make production and marketing decisions without knowing with certainty future price and output. Therefore, farmers must make their decisions in an environment of uncertainty where time is also a decisive factor. Thus, the relative performance of different production and marketing strategies in terms of risk-returns is of great interest to farmers, and is the primary objective of this study.

BACKGROUND INFORMATION

Farmers are typically assumed to be in general risk-averse and to have a certain trade off between risk and estimated revenue. For crop farmers, revenue comes from crop sales and government support payments. According to Hanson et al. (1999) as a result of the change in the role of the government after the 1996 farm bill, farmers have greater responsibility for using their own risk-management programs. The price support programs were reduced, generating a riskier situation for crop farmers selling their products. Given this prevailing economic climate, it is important to direct research focus on the ability of marketing and hedging strategies to reduce return risk for cotton and soybeans farmers in Mississippi County, Arkansas.

[1]Research Specialist, associate professor, and associate professor, respectively, Department of Agricultural Economics and Agribusiness, University of Arkansas at Fayetteville.

RESEARCH DESCRIPTION

Thirty-seven marketing strategies developed in this study are summarized in Table 1. Each strategy represents a portfolio (combination) of different hedged (cash and futures) positions for cotton, soybeans, and crop mix enterprises. The possibility of utilizing hedging strategies adds potential further risk-reduction benefits to the crop-mix enterprise. Cash only strategies are also included as a means of comparing hedging effectiveness. Each strategy is analyzed in terms of net returns generated on a per-acre basis. The simulation model characterizes the risk-return profiles faced by cotton and soybean producers in Mississippi County, Arkansas. Yield data were gathered from the National Agricultural Statistics Service (NASS). Alternatively, cash price data were obtained from the Memphis cash market in Tennessee and futures price data were obtained from the New York Cotton Exchange (NYCE) and the Chicago Board of Trade (CBOT). Yield and price data were collected for the years 1981-2000. Production costs were calculated from budgets generated by the Arkansas Cooperative Extension Service (CES).

Simulated distributions of net returns above total costs for cotton and soybean crop enterprises under different marketing strategies are evaluated using stochastic dominance with respect to a function (SDRF). Under this approach, the different marketing (hedging) strategies associated with different crop enterprises can then be ranked in terms of their risk-return characteristics. The marketing dates for the 37 strategies are determined by the respective harvest time for each crop. Out of the 37 strategies, six are cash positions and 31 are hedged positions that begin in June for soybeans and in May for cotton, and end with sale dates in November and December, respectively. As such, the hedging strategies simulate traditional hedges, initiated at planting time and offset at harvest time. The variation in the strategies is based upon the level of hedging, or the proportion of expected production covered by hedging.

RESULTS AND DISCUSSION

The SDRF ranking of the 37 marketing strategies is presented in Table 2 using a RAC of zero (risk-neutral) and a RAC of 0.5 (extremely risk-averse). This table also shows the rank for each marketing strategy with respect to the different enterprise types for the two different RAC levels. Assuming risk neutrality (RAC = 0), cash-only and hedging strategies (1 to 8) associated with cotton only enterprises would be preferred to equivalent hedging strategies (9 to 16) for soybeans-only enterprises. These cotton strategies ranked in the first eight positions. The equivalent soybean strategies ranked in the last eight positions with the exception of strategy 15 (naive soybeans hedge 100% futures position against 100% cash position), which ranked 29th. Strategies for crop-mix enterprises (strategies 17 to 31) ranked from 11th (strategy 29) to 26th (strategy 31, the optimal revenue risk-minimizing strategy).

The most preferred strategy was the cotton 100% cash position with no hedge (strategy 1). On the other hand, the equivalent 100% cash soybeans position with no hedge (strategy 9) ranked in last position. When the degree of risk is irrelevant, a farmer would prefer marketing strategies associated with cotton enterprises as they generated the highest net returns. Alternatively, when a farmer is extremely risk averse (RAC = 0.5), strategy 1 ranked 34th. Therefore for a cotton enterprise with extreme risk aversion, results imply that selling in the harvest-time cash market would be one of the least preferred marketing strategies. Under the extreme risk-aversion assumption, the SDRF criterion used in this study give cotton enterprise strategies a low ranking. This is due to the fact that net revenues generated by selling in the harvest-time cotton cash market have a large standard deviation and the minimum potential loss associated with any hedging level is large (ranging from $110/ac up to $140/ac). Short hedging is moderately effective only at low levels of coverage (e.g., 25%, 33% and 50% hedging strategies are preferred to the cash marketing strategy).

In contrast, marketing strategies associated with soybean enterprises are preferred when farmers are extremely risk-averse. However, this result is not attributable to effective hedging. The larger the amount of expected production covered by short-hedging, the poorer the strategy's performance. The best strategy for a soybeans-only enterprise is to simply sell in the cash market without hedging (strategy 9 – which ranks 2nd overall). Thus, the preference for marketing strategies associated with soybean enterprises over strategies associated with cotton enterprises may be attributed to the low standard deviation of net returns and to the relatively small minimum potential loss ($80/ac) generated by selling in the soybean harvest cash market. The most preferred risk reducing strategy (assuming extreme risk aversion) is crop-mix hedging strategy 31, the optimal revenue risk-minimizing strategy). However, this strategy was desired from a statistical model and would not likely be used in an applied setting.

In summary, under the SDRF criterion, hedging is ineffective for soybean enterprises, while hedging at moderately small levels (25% to 50% short hedges) is preferred to a cash marketing strategy for cotton enterprises. Diversification may reduce risk but may also reduce the level of returns. SDRF provides a good approach to analyze the potential benefits of diversification in this risk-return trade-off framework since it takes into account both the level of returns as well as the risk associated with those returns when ranking strategies.

PRACTICAL APPLICATION

The importance of this study is highlighted by the fact that no other pre-harvest row-crop marketing studies have been conducted for the state of Arkansas using crop-mix hedging strategies. In addition, previous Arkansas studies, which have analyzed revenue risk (i.e., yield risk and price risk), have used a simplified model to explain the impact of price variability on revenue risk by assuming farmers receive a seasonal average cash price. The results of this study show that existing marketing tools in the form of futures price hedging can be used to reduce revenue risk (i.e., yield risk and price risk) for Mississippi County cotton farmers.

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Table 1. Cotton, soybeans, and crop-mix marketing strategies examined for Mississippi County, Ark., in 2003.

Number	Cash position	Hedge position[1]	Cash position	Hedge position[1]
1	1.00	0.00	0.00	0.00
2	1.00	-0.025	0.00	0.00
3	1.00	-0.33	0.00	0.00
4	1.00	-0.50	0.00	0.00
7[a]	1.00	-1.00	0.00	0.00
8[b]	1.00	-1.03	0.00	0.00
9	0.00	0.00	1.00	0.00
10	0.00	0.00	1.00	-0.25
11	0.00	0.00	1.00	-0.33
12	0.00	0.00	1.00	-0.50
15[c]	0.00	0.00	1.00	-1.00
16[d]	0.00	0.00	1.00	-0.18
17	0.68	0.00	0.32	0.00
18	0.68	-0.25	0.32	0.00
19	0.68	-0.33	0.32	0.00
20	0.68	-0.50	0.32	0.00
23	0.68	-1.00	0.32	0.00
24	0.68	0.00	0.32	-0.25
25	0.68	0.00	0.32	-0.25
26	0.68	0.00	0.32	-0.25
29	0.68	0.00	0.32	-1.00
30[e]	0.68	-1.00	0.32	-1.00
31[f]	0.68	-1.14	0.32	5.37
32[g]	0.00	0.00	1.00	-0.84
33[h]	1.00	-1.07	0.00	0.00
34i	0.68	-1.03	0.32	-0.82
37	0.25	0.00	0.75	0.00

[1] A negative number indicates a short hedge position and vice-versa
[a] Naive cotton hedge 100% cotton cash, 100% cotton futures
[b] Optimal risk minimization hedge ratio for 100% cash cotton
[c] Naive soybean hedge 100% soybean cash, 100% soybean futures
[d] Optimal risk minimization hedge ratio for 100% soybean cotton
[e] 100% hedges for proportional cash positions in cotton and soybean
[f] Optimal risk minimization hedge for proportional cash positions in cotton and soybean
[g] Optimal price risk minimization hedge for 100% soybean
[h] Optimal price risk minimization hedge for 100% cotton

Table 2. Rankings of 37 marketing strategies based on SDRF for cotton, soybeans and crop-mix enterprises in Mississippi County, Ark., in 2000.

					Risk-aversion coeficient (RAC) Rank	
Cotton position		Soybean position				
Marketing stragety	Cash	Hedge	Cash	Hedge	Neutral	Extremely risk-averse
1	1.00	0.00	0.00	0.00	1	34
2	1.00	-0.25	0.00	0.00	2	32
3	1.00	-0.33	0.00	0.00	3	28
4	1.00	-0.50	0.00	0.00	4	26
5	1.00	-0.67	0.00	0.00	5	30
6	1.00	-0.75	0.00	0.00	6	33
7	1.00	-1.00	0.00	0.00	7	35
8	1.00	-1.03	0.00	0.00	8	36
9	0.00	0.00	1.00	0.00	37	2
10	0.00	0.00	1.00	-0.25	35	5
11	0.00	0.00	1.00	-0.33	34	6
12	0.00	0.00	1.00	-0.50	33	13
13	0.00	0.00	1.00	-0.67	32	14
14	0.00	0.00	1.00	-0.75	31	18
15	0.00	0.00	1.00	-1.00	29	25
16	0.00	0.00	1.00	-0.18	36	4
17	0.68	0.00	0.32	0.00	1	23
18	0.68	-0.25	0.32	0.00	7	11
19	0.68	-0.33	0.32	0.00	18	8
20	0.68	-0.50	0.32	0.00	19	7
21	0.68	-0.67	0.32	0.00	20	10
22	0.68	-0.75	0.32	0.00	21	12
23	0.68	-1.00	0.32	0.00	23	15
24	0.6	0.00	0.32	-0.25	25	22
25	0.68	0.00	0.32	-0.33	16	21
26	0.68	0.00	0.32	-0.50	15	20
27	0.68	0.00	0.32	-0.67	14	17
28	0.68	0.00	0.32	-0.75	1312	16
29	0.38	0.00	0.32	-1.00	11	19
30	0.68	-1.00	0.32	-1.00	22	31
31	0.68	-1.14	0.32	5.37	26	1
32	0.00	0.00	1.00	-0.84	30	24
33	1.00	-1.07	0.00	0.00	9	37
34	0.68	-1.06	0.32	-0.82	24	29
35	0.75	0.00	0.25	0.00	10	27
36	0.50	0.00	0.50	0.00	27	9
37	0.25	0.00	0.75	0.00	28	3

—— *Guest Article* ——-

REGULATION OF FIBER CELL INITIATION BY EARLY-SEASON TEMPERATURES IN AMERICAN UPLAND COTTON

H. Lewis[1]

INTRODUCTION

The components of lint yield in cotton are the number of plants per acre, the number of bolls per plant, the number of seeds per boll, and the number of fibers per seed. This list may be reduced to the two essential components, i.e., the number of seeds per acre and the weight of fiber per seed. A great deal of attention has been paid to the first factor but the weight of fiber per seed has been grossly neglected.

A recent report (Lewis, 2000a) presented strong evidence that variations in daily minimum temperatures early in seedling development dramatically influence the expression of genes that control the number of fiber cell initials in the outer integuments of the egg sac apparatus of American upland cotton (*Gossypium hirsutum*). This finding is in good agreement and strongly supports the findings of Zeevart (1966) concerning the role of temperature and day length in regulating differentiation of plant reproductive tissue. Specifically, the proposition that the mechanism by which these environmental factors exert their influence involves the activation of specific gene loci.

The earlier report (Lewis, 2000a) involved dividing the whole plant into "Fruiting Zones," which involved combining fiber from multiple bolls from different fruiting positions for subsequent analyses. This procedure could yield results which masked or obscured possibly important differences in fiber parameters from boll to boll in a given "fruiting zone". Because of this possibility, the experiment reported in this study was designed to examine individual bolls from single fruiting positions in "Fruiting Zone I", that is, the first four first-position bolls. This paper reports the results from this study.

EXPERIMENTAL PROCEDURE

The immature cotton fiber mutant (imim) was used for these studies. This mutant is controlled by homozygous recessive alleles at a single locus (Kohel et al., 1974). Mutant plants are characterized by "tight-locked" bolls with immature fibers at boll opening. The absence of significant secondary cell wall greatly enhances gravimetric techniques of estimation of the number of fibers per seed.

[1]Farmer and scientist, Hal Lewis Enterprises, Doddridge, Ark.

This is primarily due to the fact that fiber initiation and elongation are temporally separated from secondary cell-wall synthesis providing for direct estimates of the impact of environmental forces on primary cell-wall synthesis with minimum interference from secondary wall effects, which are influenced by environmental events occurring several days later.

Planting was done in replicated plots on May 6, 1997 and hand thinned to approximately three plants per foot of row. Plots were located in Mississippi County, Arkansas, about eight miles north of Keiser and 3.5 miles southwest of Dell. All agronomic practices were as prescribed by the Arkansas Cooperative Extension Service. No plant growth regulators were employed and no harvest aids were used. At open boll maturity, cotton from first-position bolls was hand-picked from first, second, third and fourth fruiting branches. This seedcotton was rigorously maintained in separate containers , being sure to keep each fruiting branch separate and free from contamination from the other three fruiting branches. Seedcotton from 30 plants was pooled for each first-position boll from each fruiting branch. These samples were weighed, ginned and subjected to intensive HVI and Afis fiber analysis. All fiber analyses were done by the Cotton Incorporated fiber laboratory, Raleigh, N.C. Daily high, low and average temperatures were obtained from the University of Arkansas Agricultural Weather Station located nearby at the Northeast Research and Extension Center, Keiser, Ark.

Emergence was determined, by visual observation, to be complete on 12 May 1997. Subsequent development sequences were based on the well established arithmetic progression of cotton fruiting-form development (Oosterhuis and Jernstedt, 1999), that is, about 3-day intervals between first-position bolls from fruiting branch (the vertical flowering interval) and approximately 6-day intervals between fruiting positions on the same fruiting branch (the horizontal flowering interval). Figure 1 is a graphical representation of the minimum daily temperatures and key developmental events. The basic design of this experiment assumes that leaf primordia begin initiation at or about emergence with the unfurling of the cotyledons and exposure of the epicotyl to the environment (Mauney, 1986). All measurements of fiber initiation and development are based on this starting point and the classical arithmetic progression of 3 days between elaboration of fruiting forms on sequential fruiting branches. Thus, it is assumed that the elaboration and expansion of the first true leaf begins on or about the day of emergence, the second true leaf initiates these activities about 3 days later and so on until the fourth true leaf, approximately 12 days latter. A further assumption is that the daily minimum temperatures between emergence and 3 days later are the critical temperatures which would influence differentiation of the first-fruiting position on the first fruiting branch, the next 3 days for the second fruiting branch and so forth; the next 3 days for the third fruiting branch and the next three days for the forth fruiting branch. Figure 1 is a graphic/schematic representation of this experimental scheme.

RESULTS AND DISCUSSION

Table 1 shows the results of this experiment and the results of correlation analysis of all the components of the study. Weight of fiber per seed, numbers of fibers per seed, average fiber length, and weight per fiber increased from the first to the fourth fruiting branches. In addition, changes in these measures of fiber quantity per seed from fruiting branch to fruiting branch were highly and positively correlated with each other.

Based on the results of earlier studies (Lewis, 2000a), the role of daily minimum, overnight low temperatures in these phenomena was investigated. Table 1 also shows these results. The sequential 3-day average daily minimum temperatures postemergence ranged from 48.7 to 60.3°F over the 12-day period. This time-frame was predicated on the developmental scheme of 3 days between first-position bolls from fruiting branch to fruiting branch. The basic concept is that at emergence the cotyledons unfurl, exposing the apical meristem to surrounding air temperatures. At this time the first true leaf initiates expansion, which establishes the node of the first fruiting branch or the differentiation of reproductive tissue. Subsequent fruiting branches would be elaborated in 3-day intervals after the first. Figure 2 illustrates how the weight of fiber per seed changes in first-position bolls from fruiting branch to fruiting branch as daily minimum temperatures changed. Increase in weight of fiber per seed was nearly linear through the first three fruiting branches but leveled off between fruiting branches three and four. This is a polynomial regression line with a quadratic equation, which shows that the weight of fiber per seed did not increase in a linear fashion but with a continuously decreasing rate. Figure 3 further elucidates this relationship between the number (and thus weight) of fiber on the seed and the daily minimum temperature. Table 1 provides some additional insight into this relationship in that the daily average 3-day minimum temperature suffered a significant drop between the third and fourth fruiting-branch developmental sequence from about 60 to 52°F. The slope of the regression line indicates a change of approximately 329 fibers per seed with each degree change in the 3-day sequential daily average minimum temperature. These findings are in strong support of the earlier report by Lewis (2000a) that such temperatures play a critical role in the differentiation of cotton fiber cell initials. Daily maximum temperatures were less correlated with weight and numbers of fiber per seed than with daily minimum temperatures (Table 1).

The relationship between weight of fiber per seed and the number of fibers per seed is shown by Fig. 4. The slope of this regression line indicates that an increase of about 1 milligram of fiber per seed results in an increase of about 309 fibers per seed. The coefficient of determination shows that approximately 99 percent of the increase in weight of fiber per seed is accounted for by increased numbers of fibers per seed. Further examination of Table 1 shows that fiber weight per seed is well correlated with average fiber length (R=0.90) and less correlated with linear density (R=0.71). These findings strongly support the position that

fiber weight per seed is primarily controlled by the number of fibers per seed.

Overall, these data reveal the dramatic influence of the daily average minimum temperature on the number of fiber cells initiated early in the seedling stage when the corresponding true leaf is expanding and not on the subsequent development of the fiber after initiation is effected, that is, fiber length and linear density.

The most fascinating aspect of this study is the interaction of fiber-cell initial differentiation with the population of short fibers (fibers shorter than ½ inch) on the seed. This relationship is shown in Figure 5. The total number of fibers per seed increased from about 6000 to approximately 11000 from the first fruiting branch to the fourth fruiting branch. The number of short fibers per seed varied from a little over 2100 to nearly 3000 at the same time, a change of only about 900 short fibers per seed (Table 1). Nevertheless, when these values are converted to percent short-fiber content by number, a different picture arises. Namely, percent short fiber decreased from about 35% to 26% (Fig. 5.), a difference of approximately 9 percent; a highly significant change. The primary reason for the decrease in percent short-fiber content is not a dramatic decrease in the number of short fibers per seed but, instead, the large increase in the total number of fibers per seed. Thus, when these values are converted to percentages the large increase in total fibers per seed balanced against the small increase in the number of short fibers per seed results in a remarkable decrease in percent short fiber content. Percent short fiber was negatively and well correlated with average fiber length (R=-0.82), which gives an R-squared of 0.67 (Fig. 6). This finding is in excellent agreement with the earlier suggestion by Lewis (2000a) that percent short fiber may be improved in practical breeding programs by selecting for improved mean fiber length.

Review of the temperature data in Figure 1 leaves little doubt that May temperatures are highly variable and volatile. For example, between the fourth and eighth of May, daily minimum temperatures varied from 45 to 63°F, a spread of 18 degrees in 4 days. In addition, from May sixteenth through nineteenth daily minimum temperatures fluctuated from 43 to 71°F, another variation of 18°F but in only three days. Cotton growers seem to have an inchoate yearning to plant early. Data presented in this study suggest that this tendency could have undesirable effects and deserves careful study. This is especially relevant in view of the report (Lewis, 2000b) that variations in actual crop yield in the Delta region during recent years were highly correlated with the weight of fiber per seed (R^2=0.70) and poorly correlated with the number of seeds per acre (R^2=0.08).

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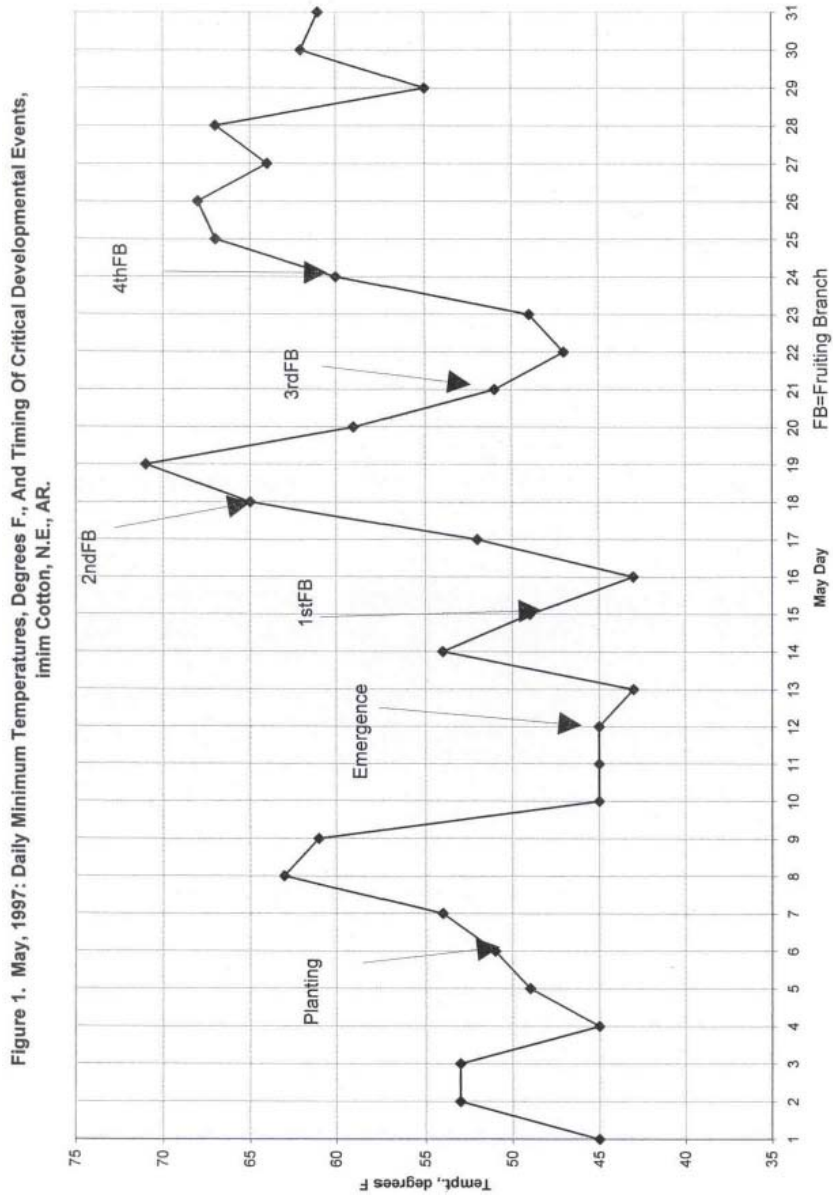


Figure 1. May, 1997: Daily Minimum Temperatures, Degrees F., And Timing Of Critical Developmental Events, imim Cotton, N.E., AR.
Planting
Emergence
1stFB
2ndFB
3rdFB
4thFB
Tempt., degrees F
May Day
FB=Fruiting Branch

Figure 2. Change In Weight Of Fiber Per Seed With Fruiting Branch (1st Position)

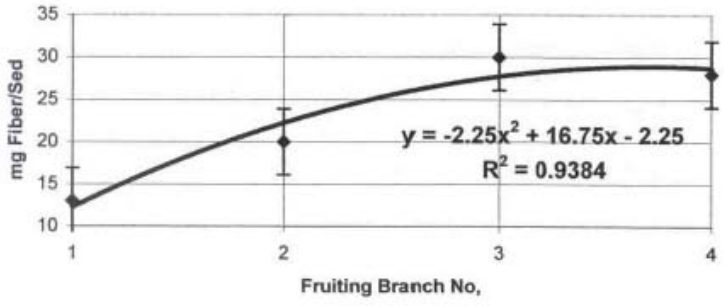


Figure 3. Change In No. Of Fibers Per Seed With Change in 3 Day Sequential Daily Avg. Min. T.

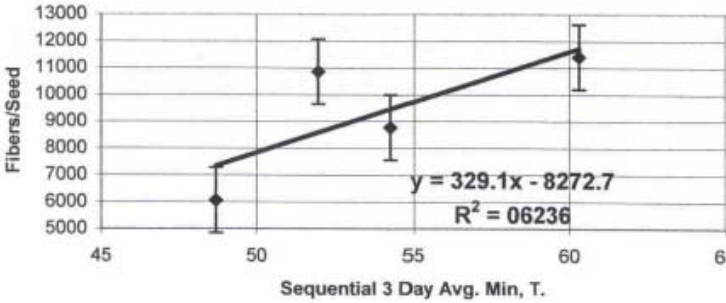


Figure 4. Change in Number Of Fibers Per Seed With Change In Weight Of Fiber Per Seed

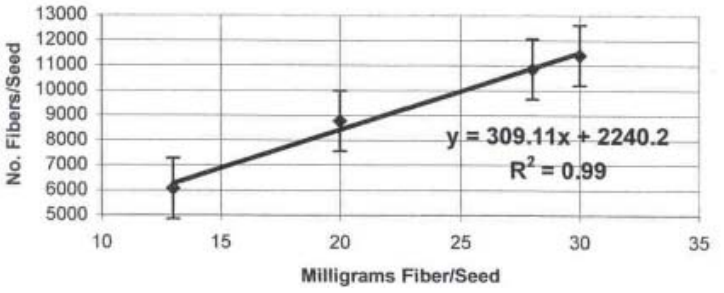


Figure 5. Change In Percent Short Fiber Content (N) With Change In No. Of Fibers Per Seed

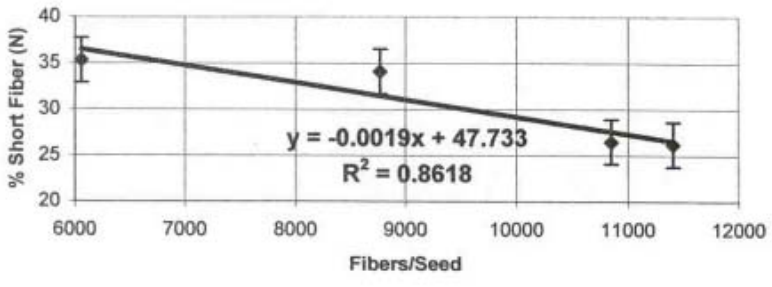
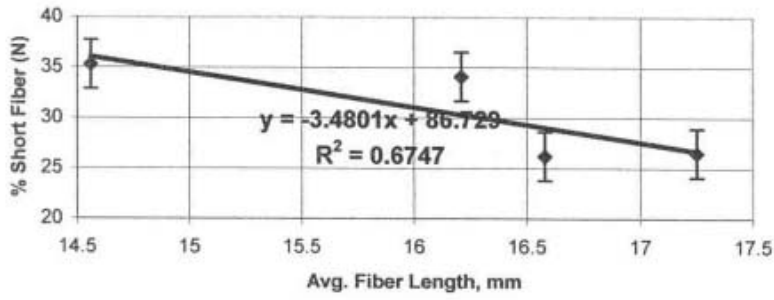


Figure 6. Change In Percent Short Fiber Content (N) With Change In Average Fiber Length



APPENDIX I
STUDENT THESES AND DISSERTATIONS IN PROGRESS IN 2003

Agudelo, Paula. A study of the diversity of geographic populations of reniform nematodes in the cotton growing areas of the U.S., and observations on compatible and incompatible reactions with cotton. (Ph.D., advisor: Dr. Robbins, co-advisor: Dr. Stewart).

Antoine, Wesner. Genotype-independent transformation of cotton with Agrobacterium. (M.S., advisor: Dr. Stewart).

Arevalo, Milenka. Effects of night temperatures on boll growth and yield, and determination of upper temperature thresholds for improving COTMAN management decisions. (M.S., advisor: Dr. Oosterhuis).

Avila, Carlos A. Transfer of reniform-nematode resistance from diploid cotton species to tetraploid cultivated cotton. (M.S., advisor: Dr. Stewart).

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Malo, Juan P. Risk-returns of major Arkansas field-crop counties. (M.S., advisor: Dr. Parsch).

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APPENDIX II
RESEARCH AND EXTENSION
2003 COTTON PUBLICATIONS

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